MODERN PRACTICAL BUILDING

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MODERN PRACTICAL BUILDING

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CHAPTER 1

BRICKS AND BRICKWORK

THE ordinary brick unit is approximately $9 \times 4\frac{1}{2} \times 3$ inches. The dimensions of most bricks are slightly less than these (see Standard Sizes). Although bricks are mostly of burnt clay, there are three materials in use :

(1) Clay.
(2) Sand-lime.
(3) Concrete.

The ordinary brick is a solid unit, though some types are indented to produce a frog or recess which in bricklaying is filled with mortar. Cellular bricks are made for use where it is desired to keep the weight to a minimum.

CLAY BRICKS

The clay from which the bricks are made is termed "brick-earth." Brick-earths vary in composition, but the average brick-earth contains about three-fifths silica, one-fifth alumina, and the remaining fifth is composed of oxides of iron, magnesium, calcium, manganese, sodium and potassium. The following is a typical analysis :

	London Brick Clay
SiO_2 (Silica)	49·5
Al_2O_3 (Aluminium Silicate)	34·3
Fe_2O_3 (Iron Oxide)	7·7
CaO (Lime)	1·4
MgO (Magnesia)	5·1
CO_2 (Carbon Dioxide)	—
H_2O (Water)	—
Organic matter	1·9
	99·9

Descriptive terms such as "common," "sand-faced," "pressed," etc., do not imply any consistent standard. It is advisable to select bricks by sample rather than description.

The Clay Products Technical Bureau of Great Britain have supplied the following classification of brick types. This gives useful information on the raw material, and methods of manufacture in relation to the characteristics of various bricks.

BRICK NOMENCLATURE

No systematic nomenclature for bricks has so far been evolved, and the designations used to-day are based on at least six different and unrelated modes of classification, viz.:

I. Place of origin, e.g. Leicester red, Luton grey, Staffordshire blue.
II. Raw material, e.g. marl, gault, blaes.
III. Method of manufacture, e.g. hand-made, wire-cut, pressed.
IV. Use, e.g. facing, engineering, common or stock.
V. Colour, e.g. often associated with origin (see I), also yellow, multi-coloured, brindled.
VI Surface texture, e.g. sand-faced, rustic, glazed.

CLASSIFICATION I: PLACE OF ORIGIN

This basis of designation has its roots in the older tradition of using local products, the particular qualities of certain of which, like Buxton lime, were outstanding enough to gain a wide reputation. Its acceptance to-day as a sole criterion would, however, be inadvisable since (owing to imitation of successful products of one locality by makers in other districts) the geographical term has, in some cases, lost the implicit recommendation of being produced from the original clay.

Nevertheless this system of classification is sufficiently widespread to warrant closer analysis of some typical examples.

Accrington, Leicester, Ruabon and Weald Bricks.—These are examples, chosen at random from a number of topographically-named bricks, which have a wide reputation as products of beautiful red colour and high strength. Like the Staffordshire blue brick, the Accrington and Weald engineering bricks are of such immense strength and durability that they stand in high favour with the engineer as a structural material. Further consideration of this point is given under "Engineering Bricks." In addition, owing to their rich red coloration and resistance to weathering, the Leicester and other reds have an excellent reputation all over Great Britain as facing bricks.

Fletton Bricks.—These bricks are made from a clay-shale which occurs in the Fletton area close to Peterborough. Produced on an enormous scale, with all the advantages attainable by the use of modern plant and scientific control, these bricks, now made in a variety of forms, are extensively used as a general-purpose brick. Their cheapness is to be attributed to an intelligent large-scale exploitation of two factors, viz.: (1) the raw clay-shale, from which the "Fletton" is made, contains combustible matter in sufficient quantity to reduce to a very low figure the amount of additional firing necessary to burn the bricks, and (2) the adoption of the high-pressure method of moulding the semi-dry clay, whereby large expenditures of time and money on drying are eliminated. The brick is reddish to salmon pink in colour with occasionally a yellowish tinge. The ordinary Fletton brick is eminently suitable for all purposes where a common brick is required. To overcome the difficulty of securing a good plaster key with all normally-shaped pressed bricks many manufacturers of Fletton bricks now produce, as a standard product, grooved Flettons for use where renderings or plaster are to be applied.

London Stock Bricks.—This designation is paradoxical since London Stock bricks are not actually made from London clay, but from deposits of limey clay which occur in Kent and Essex. This clay is mixed with a proportion of combustible matter, and after suitable preparation is either hand or machine-moulded, dried and fired either in clamps or kilns. The bricks are of yellow hue, hard and strong. As their name indicates, they are usually employed in and around the metropolis on account of their very high resistance to the London atmosphere. Their surface and texture are such as to create an excellent bond with jointing mortar, plasterwork, etc. They are marketed in six recognised grades, viz.: I. Yellow Facings (where a uniform colour is required); II. First Hard Stocks (varied colour facings); III. Second Hard Stocks (very hard, somewhat irregular shape, for foundations or cheaper facings); IV. Mild Stocks (for subsequent rendering); V. Rough Stocks (foundations, garden walls, etc.); VI. Third Stocks (backing brick).

The white efflorescence occasionally noted on London Stock masonry during the first few months after erection is of no permanent significance, and is rapidly washed away for good by the first onset of steady rain.

Suffolk Bricks.—This term, originally applied to the white or very pale yellow bricks originally made exclusively in Suffolk from mixtures of chalk and clay, is now often used to describe bricks of similar hue, produced in adjacent counties. Much used as facing bricks, Suffolk bricks, owing to their high reflecting power, can be used with advantage in enclosed courts, etc.

Luton Grey Bricks are still made in the Luton area, some by the traditional hand-made process. Like the preceding group, Luton greys are held in high esteem in the south of England as excellent facing bricks of relatively high reflecting power.

Staffordshire Blue Bricks are made from a deposit of clay rich in iron and peculiar to Staffordshire. They are extremely hard and are vitrified to such an extent that they are practically non-porous. Of very high strength, they are widely used as engineering bricks and wherever complete immunity to attack or low porosity is essential. (See "Engineering Bricks.")

There are other geographically-named bricks such as Fareham reds, Reading silver greys, Yorkshire reds, Lancashire greys, etc.

CLASSIFICATION II: RAW MATERIAL

Gault Bricks.—Usually white or cream in colour and often made with circular perforations, gault bricks are made from the black or dark blue gault clays which occur below chalk.

Marl Bricks.—Except in South Staffordshire and a few other places, the term " marl " or " malm " is applied to all clays which contain an appreciable amount of finely divided chalk or limestone particles. In preparing such clays for brick manufacture it is customary to adjust the proportions of clay to lime by suitable additions. Owing to the presence of such lime, marl or malm bricks are frequently yellowish in colour. Such a variety of bricks, however, can be made from marls that the term is of too general application to be of much service.

Shale Bricks.—After formation, a clay deposit may either remain on or near the surface, or may become buried beneath other rock strata to such a depth that it is pressure-consolidated into a class of rock known as clay-shale. Provided the consolidation has not gone too far, these shales, properly handled, constitute very suitable material for brick-making. For example, excellent bricks and other burnt-clay products are produced from the clay shales found in the Accrington district, in Staffordshire and elsewhere.

Blaes or Colliery Shale Bricks.—In coal-mining, beds of clay-shale are often encountered and, in getting at the coal, considerable quantities of such shale, frequently mixed with the debris of other rocks, are removed and dumped to form huge refuse-heaps around pit-heads. If it contains a suitable proportion of clay-shale, such colliery refuse, known as " blaes " or " colliery shale," can, with skilful handling, be converted into bricks of consistent quality. Unfortunately, produced under crude conditions at pit-heads for cheap local use, the quality of the product has usually been so indifferent as to bring discredit upon a class of brick which, properly manufactured, is quite acceptable.

CLASSIFICATION III: METHOD OF MANUFACTURE

Originally all bricks were hand-moulded one at a time by manual labour. With the advent of machinery various methods of producing moulded bricks mechanically have been developed. Some of these mechanical processes are reflected in the designations applied to types of brick, e.g. wire-cut, re-pressed wire-cut, semi-dry pressed.

Hand-made Bricks.—The traditional method of hand-making, if carried out by capable operatives, still produces the best possible type of brick. The clay, after being dug, is weathered for some time and then mixed with water and ground until it is smoothly plastic and soft. Suitable portions of this soft mass are then thrown by the hand-moulder into a brick-shaped box, the sides of which have either been wetted by water or covered with sand to enable the mould to be easily removed. The resultant " green " brick is then dried slowly and carefully to remove

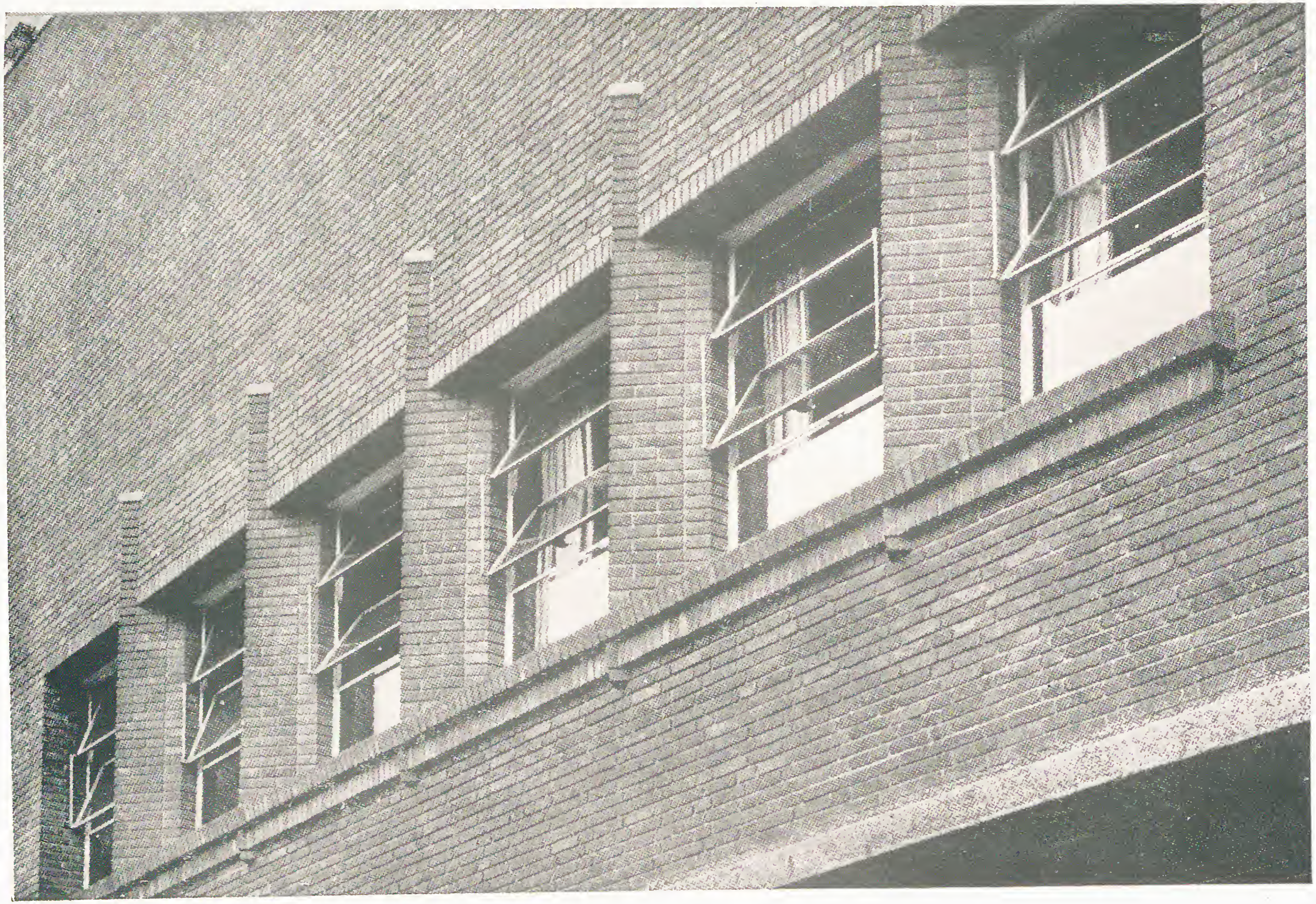


FIG. 1.—A MODERN BRICKWORK DETAIL.

The bond is a modified Flemish, consisting of one header to two stretchers in each course.

(Sir John Burnet, Tait & Llorne, FF.R.I.B.A., Architects.)

FIG. 2.—BRICK WALL, CREAM WASHED.
(Marley Tile Co., Ltd.)

the water which was added to enable the clay to be moulded. As a result of the intimate mixing of water and clay, the clay particles in the resultant brick are very closely knit together to form a good close texture of great uniformity and durability.

Mechanically-produced Bricks.—The essential difference between the various mechanical processes of brick production lies in the amount of water mixed with the quarried clay to enable the bricks to be shaped by machinery.

Wire-cut Bricks are made from clays which, by suitable treatment, are rendered sufficiently plastic as to allow them to be forced, by a series of rotating blades or screws, through a rectangular orifice. The plastic clay comes out in a continuous column, which is cut across by stretched wires to form rectangular prisms of suitable size. After careful drying these prisms are fired to produce smooth-faced wire-cut bricks which, if properly made, should have sharp arrises and show no signs of lamination.

Re-pressed Wire-cut Bricks.—In the production of this type of brick, which normally bears an impress indicative of the maker, and is indented so as to produce a frog, the drying process of the wire-cut prism is interrupted whilst the clay is still semi-plastic. The partially-hardened prisms are passed under a press which serves to compact the structure still further as well as to impress such marks and frogs on the brick as may be required.

Pressed Semi-dry Process Bricks.—In the production of this type of brick, of which the modern " Fletton " is an example, the expenditure of time, fuel and labour in plasticising the clay and drying the resultant moulded clay prisms is obviated. The clay, as it comes from the quarries, is reduced to fine granules and just sufficient water is added (by automatic apparatus) to give it a moist-earth consistence. In this state, it is compacted under very high pressure in special moulding machinery, from which it passes without further drying direct to the kilns. In recent years highly-organised manufacturers of this type of brick have so far improved the process as to eliminate, to a very large extent, the disadvantages originally attendant on the somewhat granular texture exhibited by earlier examples of brick produced by the semi-dry process. This process is capable nowadays of producing a variety of bricks of high uniformity, shape and application, and has lately been adapted to the production of various types of cellular brick.

CLASSIFICATION IV: USE

Facing Bricks.—Any type of brick which combines attractive appearance and colour with high resistance to exposure falls into the category of facing bricks. Well-known varieties of brick suitable for facings have already been mentioned and others are dealt with in succeeding sections on colour and surface texture.

Engineering Bricks.—This category of brick is probably the best example of rational brick classification, involving as it does the possession of definite properties ascertainable by test. With the advent of the machinery age the civil engineer demanded structural material of immense load-bearing capacity. This was instantly forthcoming in the form of the semi-vitrified brick, such as the Accrington, Staffordshire blue, etc. Owing to the very low porosity (usually less than one per cent.) and the vitreous character of this class of brick, the civil engineer and architect have extended their application to such jobs as sewers, engine pits, power houses; and to-day, because their maintenance costs are nil, they are again replacing their more modern rivals which, owing either to their moisture movement or sensitivity to corrosion or chemical attack, have failed to stand the test of time.

Damp-proof Coursing in Bricks.—Properly laid up in a suitable mortar, engineering bricks constitute an ideal damp-proof course of infinite durability and, properly chosen, of decorative value. A British Standard Specification covering the use of semi-vitrified bricks as damp-proof coursing materials has now been published by the British Standards Institution as British Standard Specification No. 743/1951.

Common Bricks.—This term is applied to the multifarious varieties of brick which constitute the major output of most brickyards, and which are used for general domestic and similar load-bearing construction above damp-proof course level.

Stock Bricks.—Inasmuch as these represent the "stock" always available in the ordinary brickyard, this term represents the quality of ordinary brick normally used in any area with the exception of the Home Counties, where it is usually assumed to mean the particular class of brick already described under "London Stock bricks."

CLASSIFICATION V: COLOUR

This method of describing bricks is often associated with the original place of origin, of which examples have already been given, e.g. Leicester red, Staffordshire blue, Luton grey, etc. Colour can rarely be used as a criterion of quality except when light coloration is frequently associated with underfiring. In judging an unknown variety of brick, evidence regarding its other qualities should be demanded, however attractive its colour. There are, however, certain colorations frequently met with which are known to be mere surface effects.

Multi-coloured Bricks.—These bricks of very pleasing surface coloration are produced in two ways: (1) by scattering over the surface of the unfired brick, during making, a small proportion of finely divided mineral pigment, which serves to produce purple tones on the finished brick; and (2) the manipulation of kiln fires towards the end of the firing so that, as the result of lack of oxygen, the normal red coloration is changed just at the surface of the brick to browns and purples. Here

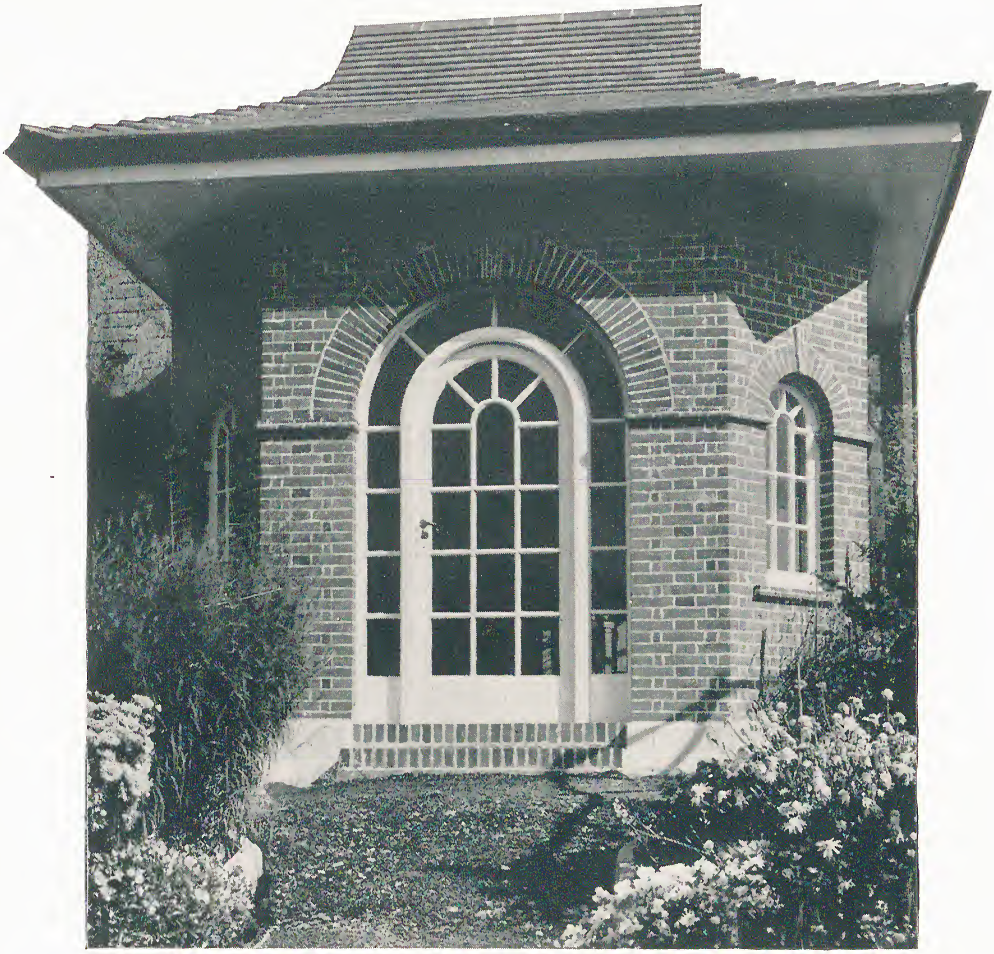


FIG. 3.—GARDEN ROOM.

Flemish-bond brickwork. Notice bonding of piers, moulded semicircular arch, with specially made windows and brick-on-edge steps. (Elliot Bros., Ltd.)

Fig. 4.—THIN FACING BRICKS WITH THICK FLUSH JOINTS, SPLAYED DOOR JAMBS, UPPER PART TILE HUNG.
(Wheatley & Co., Ltd.)

again the effect is purely superficial and the properties of the brick as a whole remain unchanged.

Brindled Bricks.—Bricks made from certain clays undergo a complete change of colour, usually from red to blue, during the final stages of the burning process. Where this is not complete a brindled effect is produced, a well-known example of which is the blue brick which is occasionally found to have red markings here and there. This change of colour takes place after the brick is fully burnt, and unless the full monochromatic appearance is of importance, the brindled brick is equally as satisfactory as the single-hued product. In point of fact certain architects have secured very striking results by the judicious use of brindled brick.

CLASSIFICATION VI: TEXTURE

Sand-faced Bricks.—By pressing a thin coating of sand into the surface of the clay prism during moulding a pleasing rough texture can be produced on the finished brick. Sand-coating the moulds in hand-making automatically produces a sand-facing. In addition, by the use of specially-selected sands, pleasing colorations can be produced. This method of producing a surface texture by sand-facing is frequently applied to wire-cut bricks.

Rustic Bricks.—This term is applied both to those bricks which have been suitably sand-faced and to machine-made bricks, the original smooth surfaces of which have been die-pressed or indented by reciprocating pins or wires so as to exhibit a rough texture closely resembling the traditional local hand-made brick.

Smooth-faced Bricks.—From the architect's point of view, too smooth a surface is occasionally unwelcome, and the various treatments already mentioned as accorded to wire-cut and other mechanically-produced bricks represent successful endeavours to overcome this objection. Where lodgment of dust, soil, etc., is to be obviated or frequent washing down is desirable (as in dairies, etc.) one smooth surface is necessary. The glazed and enamelled brick has been produced to meet this need.

Glazed Bricks.—Usually the output of special works, two types of glazed bricks are available. The brown salt-glazed brick used widely for sanitation purposes is produced by throwing ordinary salt on the brickware during the final stages of the burning, whereby a high-resistant mottled-brown glazed surface of great durability is secured.

Enamelled Bricks.—The second type of glazed brick is actually an enamelled brick usually produced by covering one face or end of special clay (often fireclay) brick with an enamelling glaze. The production of such enamelled brick, both white and coloured, has reached a high pitch of perfection nowadays despite the difficulties of producing a surfacing material which, after firing, shall have the same thermal properties as the main body of the brick. The crazing sometimes seen on earlier examples of this type of product was due to the presence of thermally-induced strains between the glaze and the underlying brick material.

STRENGTH OF BRICK AND BRICK MASONRY

Although some attempts have been made in the U.S.A. and other countries to classify bricks according to their crushing strength, such classification is of doubtful value, except in large-scale engineering construction, and the extension of the "strength complex" to the common structural brick is both difficult and unnecessary. Used normally, as in domestic architecture, etc., even the weakest types of brick have a crushing strength at least forty to fifty times greater than any stress they will be called upon to carry in such a structure. An interesting and reasonably comprehensive investigation of the mechanical properties both of representative British bricks and of masonry walls and piers built with such bricks was carried out recently at the Building Research Station, Watford. The results have been published through H.M. Stationery Office as Building Research Special Report No. 22 (The Mechanical Properties of Bricks and Brickwork Masonry). This publication is the only reliable record at present available as regards the strength of modern British bricks.

DURABILITY AND OTHER PROPERTIES OF BRICK

The durability and resistance to weather or chemical attack of properly-fired clay products is so high, that despite years of systematic investigation, no method of test correlatable with service behaviour has yet been evolved for the rapid assessment of durability. From such results of investigations as have been published certain generalisations of practical import can, however, be made.

I. For positions of extreme exposure to frost, only bricks of very close texture should be employed, since, where there is a large proportion of pores easily filled with water by simple contact, a series of hard frosts following days of continuous rain may produce enough ice in those pores to damage the brick.

II. The use of cheap, underfired brick is extremely unwise. Such underfired ware, which is never allowed to get on the market by reputable brick manufacturers, is quite liable to contain appreciable proportions of soluble salts such as magnesium sulphate (Epsom salts) and sodium sulphate (Glauber's salts). Present in excess these salts will not only give rise to unsightly efflorescences on external brickwork, but may, if the latter be covered with a rendering of plaster, in certain circumstances either dislodge or destroy such applied finish, or by travelling through the plaster, discolour and destroy ordinary wall paints.

CHARACTERISTICS

A good brick should be regular in shape, texture and colour, evenly and perfectly fired throughout, and have good sharp corners or arrises.

It should be free from flaws, stones, cracks and lumps. When two bricks are struck together, they should give out a clear ringing sound, almost metallic. As a general rule a good brick should not absorb more than 20 per cent. of its weight in water. A too high absorption renders the brick liable to decay. Except in the case of flettons, a well-known excellent stock brick which has an absorption of 20 per cent., the rate of absorption should vary from $\frac{1}{6}$ to $\frac{1}{14}$.

Bricks made from sandy clays absorb water more readily than others, and are not suitable for external facings unless built in the formation known as hollow walling, which consists of an inner and an outer wall, having a space of at least 2 inches between. This space provides air circulation, which dries out the brickwork.

In order to test the absorption properties of a brick it should be warmed to dry it thoroughly, and then weighed. After this the brick should be immersed in water until saturated, when it should be weighed again. Care should be taken to remove any water lying on the surface before the second weighing. It will be gathered from what has gone before that uniformity in the burning of bricks is an important matter, and this can be tested by breaking the brick and studying the exposed section. This should show a very slight running together or vitrification, and the texture of the broken face should be uniform. It should show no cracks, and be free from stones.

DEFECTS IN BRICKS

Both underburning and overburning of bricks cause defects. Bricks that flux, due from overburning, are called *burrs*. Underfired bricks are known as *chuffs*. These are soft and useless for building.

Bricks to be used underground in such positions as foundations and basements must not be of a too sandy or absorbent nature.

Further, with regard to colour, it was until recently regarded as a defect in the finished appearance of brickwork unless the bricks were of a uniform colour throughout the area of the walling. Of recent years, however, a change of opinion has taken place with regard to this, and so long as the bricks are of equal merit in other characteristics, a certain roughness of texture and variety of colour are now welcomed.

SIZES

Although in calculating wall thicknesses, heights and lengths it is convenient to accept the old nominal size of 9 inches long, $4\frac{1}{2}$ inches wide, 3 inches thick, most bricks are smaller.

Standard Sizes.—British Standard Specification No. 657 specifies three brick sizes. The difference is in the thickness only—all are of the same length and width, as follows:

Standard length: $8\frac{3}{4} \pm \frac{1}{8}$ inches.
Standard width: $4\frac{3}{16} \pm \frac{1}{16}$ inches.

There are three standard thicknesses: 2 inches, $2\frac{5}{8}$ inches and $2\frac{7}{8}$ inches.

The $\pm$ tolerances are necessary to allow for the fact that clay shrinks and distorts in burning and it is impossible to make bricks of absolutely consistent size. Thicknesses may vary $\pm \frac{1}{16}$ inch.

In addition to the standard sizes there are many special sizes. Bricks are made in a variety of thicknesses from 1 inch to 3 inches.

Briquettes are made for brick fireplaces and ornamental brickwork. These are smaller than standard bricks: $6 \times 2 \times 1$ inches and $6 \times 2\frac{3}{4} \times 1\frac{3}{4}$ inches being two common sizes.

There are also bricks moulded to special shapes, such as sill and coping bricks. Manufacturers have their own stock sizes and shapes.

STRENGTH OF BRICKS

The following tables, dealing with the strengths of bricks, are given in *Modern Brickmaking*, by A. B. Searle, to which the reader is recommended if he desires to make a thorough study of the whole process of brickmaking.

TABLE I

This table gives some indication of the range of crushing strength of a large number of bricks examined by A. B. Searle.

	Tons per square foot.
London Grey Stocks	95
Suffolk White Bricks and Gault Bricks	135
Essex Red Sand Stocks	96
Leicester Red Bricks (Wire-cut)	275
Fletton Bricks	255
Staffordshire Blue Bricks	483
South Yorkshire (Stiff-plastic process)	272
Dutch Clinkers	492
Rubber Bricks and Cutters (very variable)	74

TABLE II

The figures in this table are the result of tests made by W. C. Popplewell and Professor Unwin.

Kind of Brick.	First Crack at tons per square foot.	Crushed at tons per square foot.	Authority.
Aylesford Red, Pressed	71	141	Unwin.
Rugby, Common Red	158	190	Unwin.
Leicester Wire-cut	115	229	Unwin.
Manchester Wire-cut	87	264	Popplewell.
Manchester Common Red	74	120	Popplewell.
"Engineering" Pressed	110	290	Popplewell.
"Engineering" Pressed	160	280	Popplewell.
Red, Shale	67	220	Popplewell.
Enfield Shale, Red	205	496	Popplewell.
Accrington Plastic (Huncoat)	118	250	Popplewell.
Digby Colliery (Notts)	248	353	Unwin.
Common Blue, Staffordshire	240	353	Unwin.
Blue Staffordshire	282	356	Popplewell.
Blue Brindled, Staffordshire	204	485	Popplewell

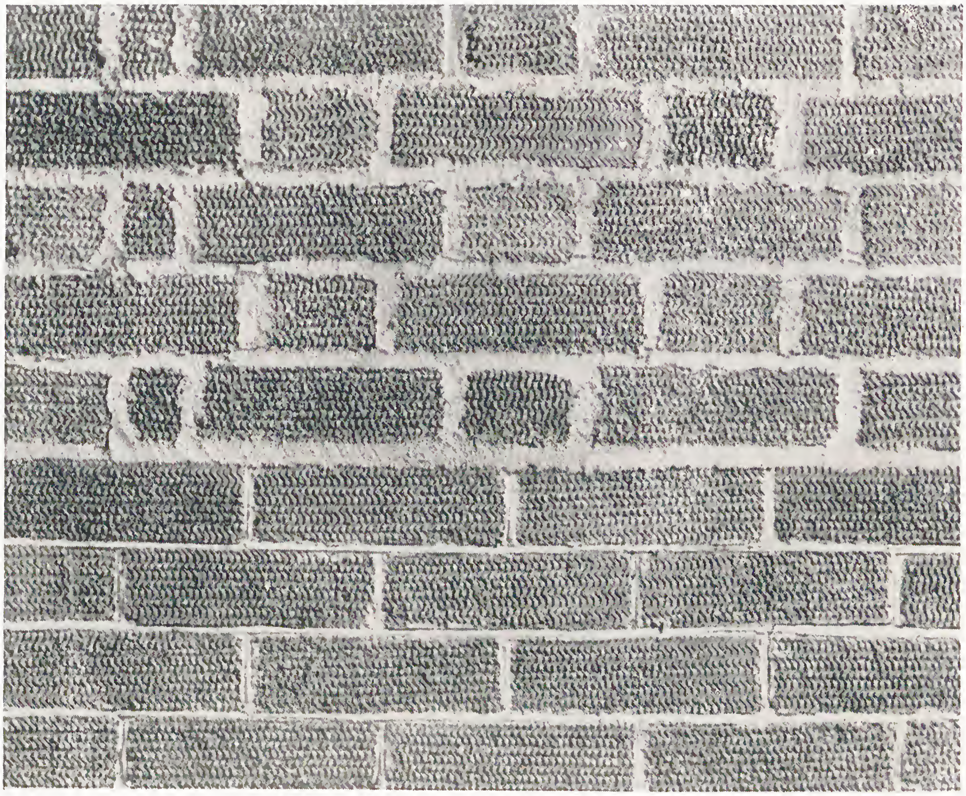


FIG. 5.—" RUSTIC " BRICKS: A CONTRAST IN JOINTING.
The thick joints in the upper part suit these rough-textured bricks better than the thin-ruled joints below.

TABLE III

The following figures give the suggested minimum strengths for building bricks in tons per square foot:

Blue Bricks and Clinkers	300
Hard Burnt Facing Bricks	250
First-class Common Bricks	150
Second-class Common Bricks	90

A list by Unwin, giving fuller detail, is the following:

Description	Dimensions in inches.	Cracked at tons per square foot.	Crushed at tons per square foot.	Colour.	Remarks.
London Stock, max.	9·2 × 4·3 × 2·8	—	185	—	Twelve from different localities.
London Stock, min.	9·8 × 4·0 × 2·5	84	89	Yellow	
London Stocks, mean	9·0 × 4·2 × 2·6	—	121	—	
Aylesford, Common	8·9 × 4·4 × 2·7	48	183	Pink	—
Aylesford, Common	8·9 × 4·4 × 2·7	111	228	Pink	—
Aylesford, Pressed	9·1 × 4·3 × 2·7	71	141	Red	Frog.
Grantham, Wire-cut	9·2 × 4·2 × 3·2	—	83	Red	—
Leicester, Wire-cut	8·9 × 4·5 × 3·2	228	246	Red	—
Leicester, Wire-cut	9·1 × 4·2 × 2·8	115	229	Red	—
Leicester, Wire-cut	4·4 × 4·2 × 2·7	225	365	Red	Mean of 7 half-bricks.
Gault, Wire-cut, max.	8·9 × 4·3 × 3·0	119	198	White	—
Gault, Wire-cut, min.	8·7 × 4·1 × 2·7	89	145	White	—
Gault, Wire-cut, mean	8·8 × 4·2 × 2·8	—	178	White	—
Arlesley White, max.	9·1 × 4·2 × 2·9	—	207	White	—
Arlesley White, min.	8·8 × 4·1 × 2·7	50	107	White	—
Arlesley White, mean	8·9 × 4·2 × 2·7	—	161	White	—
Arlesley White, Wire-cut	9·0 × 4·2 × 2·7	151	239	White	—
Coventry	4·5 × 4·4 × 3·0	—	256	Red	Half-brick
Fletton	8·6 × 4·2 × 2·7	137	203	Pink	
Fletton	8·8 × 4·1 × 2·7	126	169	Pink	—
Fletton	8·6 × 4·2 × 2·7	199	239	Pink	—
Glazed Brick	8·8 × 4·4 × 3·3	69	166	White	Frog.
Glazed Brick	8·9 × 4·4 × 2·9	166	174	White	Frog.
Kentish Stock, max.	9·3 × 4·4 × 2·9	107	127	Yellow	—
Kentish Stock, min	9·1 × 4·3 × 2·8	30	54	Yellow	—
Kentish Stock, mean	9·2 × 4·4 × 2·9	—	82	Yellow	—
Staffordshire Blue, max.	9·0 × 4·5 × 3·2	763	807	Blue	19 Half-bricks
Staffordshire Blue, min.	8·9 × 4·1 × 2·7	152	296	Blue	
Staffordshire Blue, mean	9·0 × 4·2 × 2·9	—	564	Blue	
Stourbridge	8·8 × 4·3 × 2·8	157	209	Yellow	—
Stourbridge	9·0 × 4·3 × 2·8	161	242	Yellow	—
Stourbridge	9·0 × 4·3 × 2·7	—	300	Yellow	—
Red Rubbers, max.	10·1 × 4·9 × 3·4	—	93	Red	—
Red Rubbers, min.	9·9 × 4·8 × 3·3	36	67	Red	—
Red Rubbers, mean	10·0 × 4·9 × 3·4	—	77	Red	—
Red Rubbers, three in column, bedded in putty	9·0 × 4·5 × 8·0	—	25	Red	—
Terracotta Block	6 inches square	—	168	—	—
Terracotta Block	15 inches square	—	139	—	—
Terracotta Block	15 inches square	—	267	—	—
Terracotta Block	6 inches square	—	104	—	—

MANUFACTURE

The following methods are employed for making bricks:

The Plastic Process, the Stiff-plastic Process, or Semi-dry or Semi-plastic Process.

In the Plastic Process bricks are made by hand and machinery, when they are known as Wire-cut. In this machine the clays are prepared, and broken up in a pug mill fitted with a mouthpiece of the size of the end dimensions of a brick, through which the clay is pushed. The clay is then cut into sections the length of a brick.

In order that the bricks may be placed direct into a kiln without being dried, the *Stiff-plastic Process* is used. This is not suitable for the surfaces of plastic clays.

For clays which are suitable for grinding into a powder sufficient to pass through a sieve, the *Semi-plastic Process* is used. For this process clays of a shaly nature are used.

The actual process of making the brick consists of digging the clay from the ground, washing and grinding as already described, if required, pressing, or moulding, drying, and burning. Where the clay is washed through a mill it is afterwards run through a grid which retains any stones, and led into a pit called a settling pit, where it is allowed to lie for three or four months to weather. It is generally dug out in the spring and cut into vertical sections, when it is turned over three or four times, and barrowed to the moulding press.

Hand moulding is still carried out in many parts of the country, especially in the South. The development in machinery has caused the hand-making process to be given up in many parts. The hand mould consists of a box 10 × 5 × 3 inches, constructed of wood or iron, these oversize dimensions being to allow for shrinkage. This mould has neither top nor bottom, but is placed over a fillet. It is then wetted or sanded, and a lump of clay previously kneaded is forced in by hand. This is next struck off with a wood fillet and the raw brick is turned out of the mould.

Drying.—The moulded clay, called a raw brick, is then stacked in a drying shed, which consists of a floor and a roof. They are left until dried out, ready for burning, for times varying in accordance with the weather conditions. The average time taken in hack drying is from three weeks to six weeks.

Burning not only drives the water out of the clay, but fuses the constituents to a certain degree, which gives the necessary hardness and strength. They are burnt in *clamps* in small and old-fashioned yards, and in *kilns* in the more up-to-date brickworks. The kiln consists merely of a layer of bricks on a raised surface, upon which a series of square flues is constructed, and in these the fires are placed. Over these flues, a further two courses of bricks are laid, and on these a layer of raw bricks on edge are placed together. About 6 inches of breeze is spread over this layer of raw bricks, and over this again is laid another. Above these the bricks are built up in unbonded walls to a convenient height of about 12 feet to 15 feet. The fires are then lit, and the time of burning varies from two to six weeks.

Kiln Burning.—The kilns used in burning bricks consist of either a single chamber, a number of chambers, or tunnel kilns, through which the bricks pass on trolleys, being burnt during their passage through the tunnel.

The simplest form of kiln is the *Scotch Kiln*, which consists of four walls without a roof. There may be two or more chambers, having walls perforated for fire holes. The bricks are stacked in such a way that the fire passing through these may be drawn through and around all the bricks from the bottom to the top.

The more elaborate kind of kiln is that known as the *Hoffman* or *Continuous Kiln*. This is circular in plan, and is divided up into twelve or more chambers, with loading doors, fire holes, and flues connected to a central chimney. The object of the several chambers is that the bricks stacked within may be undergoing different stages of burning at the same time. The firing is regulated from above by dampers.

The Tunnel type of kiln consists of a tunnel over 50 feet in length. The bricks are stacked on trolleys, which run on a single rail through the tunnel. The burning takes place at the centre, where the heat is greatest, and as the trolleys pass towards the exit end of the kiln, they are cooled by the current of air. This current of air also assists in the drying of the unburned bricks before they reach the centre.

VARIETIES OF BRICKS

Stock Bricks.—This term is now generally taken as meaning a hand-made brick of London clay, though correctly it should mean any brick in general use in any district made from local clay. These are good hard bricks of light yellow colour shading to browns and buffs. They are coarse in texture and of a porous appearance owing to the fact that the fuel is mixed with the clay. The particular feature rendering them suitable for use in London is their characteristic of "case-hardening." This consists of the formation of a skin on the outside, when subjected to atmospheric changes, resulting in a protection against the elements. *Flettons* are made by a semi-dry process, and burnt in continuous kilns in the Peterborough district. They are light pink in colour, and are used mostly for internal work and for backing facing bricks. Their smooth faces do not afford a good key for plastering, but special grooved bricks are now supplied for this purpose. A further development in the manufacture of flettons with a view to improving their appearance as external bricks is now provided in the brick known as the *Rustic Fletton*. This has a crimped surface on one face, given whilst in the press. A variety of colours is now to be obtained in these rustic flettons. This contributes to the wall a varied effect in colour and texture.

A third kind of fletton is that known as the *Cellular Brick*, which has been designed to overcome the excessive weight in proportion to the strength ratio which is a failing of most bricks, when bricks are to be used in positions where weight is a matter for consideration, such as, for example, with steel-framed construction, where the saving in weight is not only an economy but a necessity In addition, the cellular type of brick gives improved insulation from heat, sound, and moisture. These cellular bricks are to be obtained in plain, rustic, and keyed types all $2\frac{5}{8} \times 3$ inches. The section of the brick shows three sinkings divided by two cross bars, open on the one side, and with a thin facing on the other.

A fletton is also made known as the *White Facing*, suitable for the facing of areas in substitution for glazed bricks.

The best *Red Facing Bricks* are to be obtained from the neighbourhood of Reading, the *T.L.B.*s of Bracknell, Berks, being known throughout the country.

Rubbers, which are a soft sandy brick made by hand, are also made in the same district. The name rubber is explanatory of the use to which the brick is put in gauged brickwork. In order to obtain the fine joints in gauged work, the bricks are rubbed down until a fine level surface is obtained, enabling them to be placed close together and jointed in fine putty.

Pressed Bricks are machine-made bricks, mostly coming from the northern counties, where it has been said the bricks are of larger dimensions.

Gault Bricks.—These bricks are made from a bluish clay, and are of a bluish colour when burned. But where the clay contains a proportion of calcium carbonate, the resultant brick is hard and white.

Suffolks, which are also called ***White Suffolks,*** are kiln burnt, are especially made for facings, and are of a light cream colour.

Midhurst Whites are also a white brick used for facings, said to be very suitable for use in sooty and sulphurous atmospheres of cities. It is also claimed for them that they are immune from efflorescence and frost. These are another substitute for glazed whites. The Midhurst white is a calcium-silicate brick giving the following results on test :

Crushing Load	3,260 lb. per square inch.
Crushing Load	209 tons per square foot.
Porosity	9·31 per cent.

Blue Bricks are made in Staffordshire, the blue colour being caused by a high percentage of oxide of iron which, under very high temperature, is converted into black oxide. They are mainly used for engineering work, or for piers which are required to carry heavy loads. They are also used, when specially pressed, for copings, channels, or as paviors.

Firebricks are made from clays known as refractory clays. The meaning of refractory is the power to resist heat. This arises from the clay already having been heated to a very high temperature and caused to disassociate and become crystalline ; and thus is formed sillimanite, which is a felted mass, harder, more acid proof, and more resistant to sudden changes in temperature. The storing of firebricks is an important matter, as they are particularly sensitive to rain and frost. Good firebricks must not fuse in a temperature of 2,876° Fahr. They are used for lining furnaces and in other positions exposed to great heat, being set in refractory clays or special cements.

Fireclay is found at Stourbridge, also at Poole in Dorset, at Stamford in Lincolnshire, and in the West of Scotland.

Glazed Bricks are used in positions where it is required to keep the walls clean by frequent washing, such as corridors, larders, sculleries, and lavatories; the white variety is also used for exterior work in courts, and light wells. Glazed bricks are also to be obtained in yellow, brown, and red. Bricks which are to be glazed require careful pressing, as the joint of the finished brickwork must be a very narrow one. A variety of materials is used for glazing the bricks, depending upon the finished colour desired, and the temperature at which they are to be burned. For high-class glazed brickwork the bricks are dipped in specially prepared glazings, after the face of the brick has been prepared with a "body" composed of white burning clay. One coat of "body" is brushed on, and then each brick is dipped into a tub of "body." Where it is required to have two faces dipped, the operation is one requiring considerable skill. The shed where the dipping takes place must be of an even temperature. The glaze is also applied by dipping within two hours after they have been "bodied." The burning is carried out in kilns at a very high temperature, and the bricks must be stacked in such a manner that they do not run any risk of being chipped.

Where a cheaper glazed brick is required, this is to be obtained by heating the bricks in a down-draught kiln into the fire holes of which salt is thrown. The salt then combines with the clay at the surface of the brick, and thereby becomes part of the brick, and is consequently more durable.

Enamel Bricks.—Though this term has been applied to enamel bricks generally, its correct application is to those which are formed with a coating of opaque glaze. Enamel bricks are now manufactured by enamelling the brick and burning in one burning to fix the tint. Biscuit ware is produced by covering the brick partially burnt with a coating of the enamel, and afterwards continuing the burning of the brick

Glazed bricks which are not sufficiently fired before or after the operation of adding the salt are known as "scummed" bricks. This defect can be cured by refiring at a higher temperature.

In salt-glazing bricks, a second batch of salt is sometimes added when the temperature has reached a certain degree.

Paviors.—The bricks used for pavings in buildings mostly consist of Blue Staffordshires, but Dutch Clinkers and Adamantine Clinkers are also used. Dutch Clinkers are $6 \times 3 \times 1$ inches, vitrified throughout, whilst the Adamantine Clinkers are denser, harder, and heavier.

Hollow Bricks.—For use in positions where weight is a matter of importance, bricks formed with perforations, or in the nature of hollow blocks, are used. The hollow block is really terracotta, and is provided with a series of tubes running through the brick from end to end. Such blocks form the base of many patent fireproof floorings. Perforated bricks are made by a special press, having bars the size of the required perforation fixed in the mouth of the pug mill.

For the construction of tall chimneys, a perforated brick known as a Radial Brick is used. These are wider on the outside edge than on the inside edge, so when laid form a circle. They are made by the wire-cut process, but may also be made by the stiff plastic process, when dies of the required shape are used.

Where lightness is very essential, and in positions where it is required to obtain fixings into the brickwork by nailing, *Porous Bricks* are used. These are formed by mixing a material which will burn, such as sawdust with the clay. During the burning operation, the sawdust burns out, leaving the perforated or porous clay.

Ornamental Brickwork.—Bricks covered with ornamentation and the component parts of mouldings in brickwork are made by special metal-lined moulds, the mould being formed on a brick of the required design, carved in plastic clay, after the manner of the manufacture of moulded terracotta.

Sand-lime Bricks.—A brick of very sound practical properties, the manufacture of which has been greatly improved in recent years. Sand-lime bricks are made in white, cream and grey, and in surface textures from rough to very smooth. The latter may be used as a cheap light, reflecting wall surface instead of the more costly white glazed bricks. The sand-lime brick is formed of a base of silica, such as sand, slate or granite waste, boiler ash and furnace slag being used also, thoroughly mixed with hydrated lime. The manufacture consists in subjecting the material to a high pressure, and then exposing the brick to the action of saturated steam, for periods varying from six to twenty-four hours. They may be further matured by stacking in the open air for three weeks.

The sand-lime brick is a calcium-silicate brick, that is to say, there must be a true combination of clean siliceous sand with a high percentage of lime. In mixing, 5–10 per cent. of lime is added to the sand, and the more siliceous the aggregate is, the more lime will be taken up into combination with it, resulting in the strongest sand-lime brick. The mixing of the sand and lime is performed in an ordinary mortar mill, at first in a dry state. When thoroughly mixed a sprinkling of water is added, sufficient to make the ingredients adhere loosely. Where an hydraulic lime is used the mixture must be allowed to stand for two or three days. A well-proportioned sand-lime brick, after it has been pressed, is sufficiently strong to bear considerable weight upon it. It is then stacked on trolleys and run into boiler-shell cylinders, fitted with steam-tight doors and steam pipes. The steam is admitted at a pressure of 160 pounds per square inch.

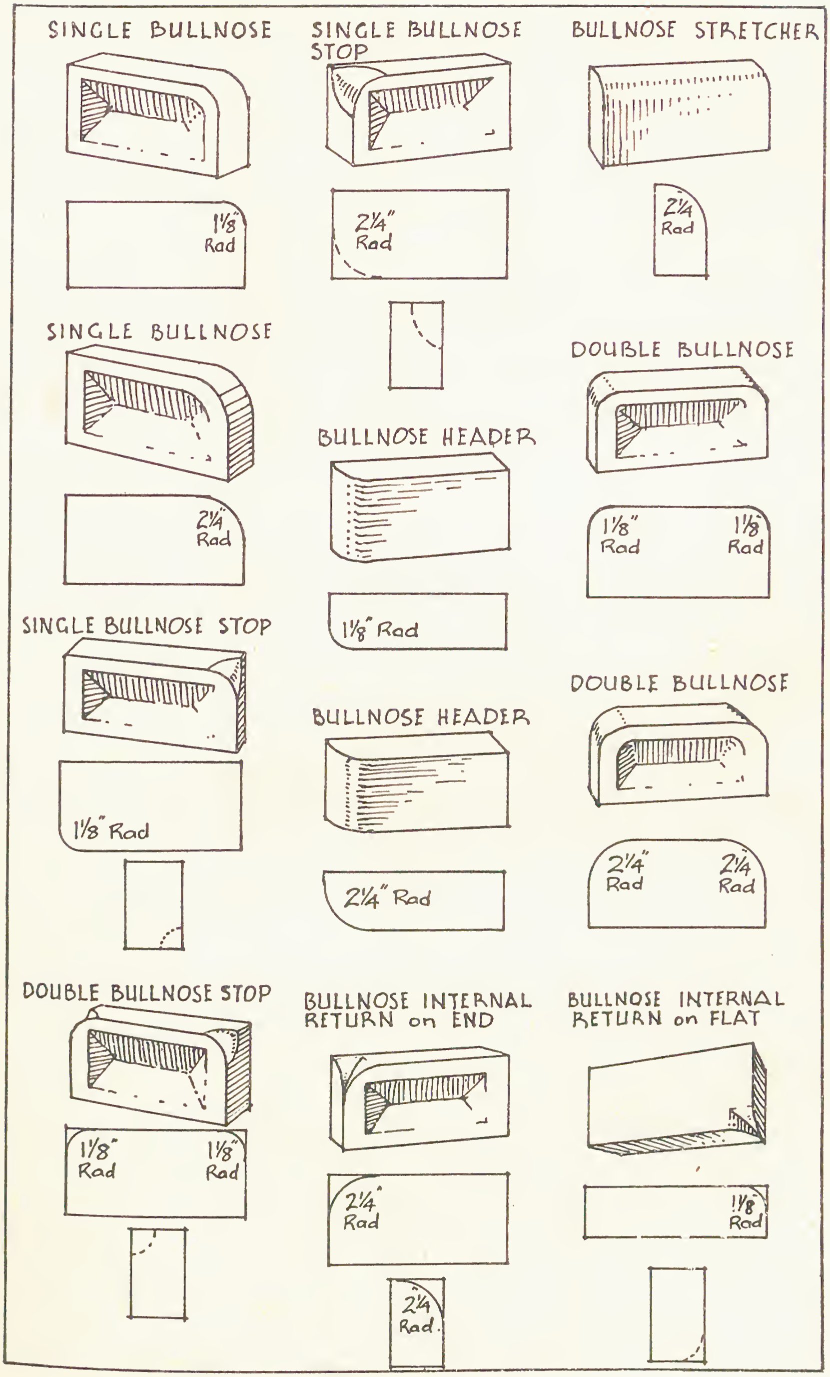


Fig. 6.—Bull-nose bricks, $2\frac{1}{4}$ inches, $1\frac{1}{8}$ inches radii.

In another method of manufacturing sand-lime bricks, ferro-concrete hardening chambers are used. In these the steam is admitted at a pressure of a few pounds per square inch, and a considerable saving is effected thereby. Perhaps the most satisfactory use for the sand-lime brick is as a backing and lining for brickwork faced with ordinary burnt bricks.

Cement Concrete Bricks.—Though hardly coming within the present subject, it may be mentioned here that bricks are now manufactured of concrete. They are composed of clean, sharp sand in combination with Portland cement in the proportions of 6 to 1 for hand-making, and 9 to 1 for power tamping. Chalk is sometimes substituted, when the proportions can be carried to 12 to 1. Blue Lias Lime, with 5 per cent. of plaster of Paris, will make a quick-setting second-class brick. The bricks should be stacked on racks, sprinkled with water, and left to harden for two days. They are then restacked with larger spaces between them, and sprinkled twice a day for a fortnight, when they can be used, though they do not attain full strength under a month.

Concrete bricks which may be used a week after manufacture can be made by adding 10–15 per cent. of hydrated fat lime, but they are apt to disintegrate. A better quick-setting concrete brick is to be obtained from using one of the rapid-hardening cements. Perhaps the main use of these bricks is to be found in districts where the transportation costs on clay bricks are a serious item. The ingredients for the concrete brick being obtainable close at hand, the bricks may be made near or upon the site.

Sand-faced Bricks.—This is the term given to describe the face imparted to the brick by the sand thrown into the mould before the clay is pressed.

WALLING

The Size of a Brick, as has already been explained, is approximately $9 \times 4\frac{1}{2} \times 3$ inches. These are average sizes used in drawings, the actual sizes of the standard bricks having already been given.

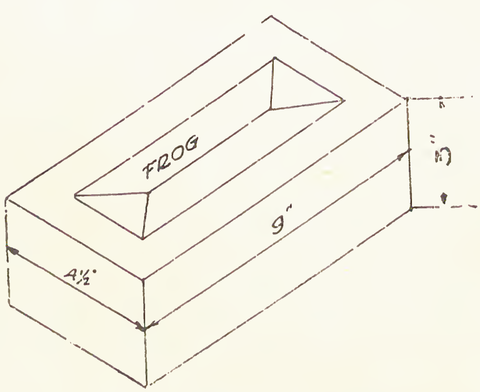


Fig. 7.—Nominal brick sizes.

In ordinary walling the bricks are laid on the $4\frac{1}{2} \times 9$-inch face, with the *Frog* or *Sinking*, where there is one, uppermost. They are laid in the wall either longways with the 3×9-inch face showing—this is known as the *Stretcher Face*—or they are laid across the wall with the $4\frac{1}{2} \times 3$-inch face showing—this is known as the *Header Face*.

The angles of a brick are called the *Arrises*, and any portion of a brick is called a *Bat*.

As will be explained below, the

bricks are laid in the walls by different methods of arrangement which are known as *Bonds*, and in all brickwork, whatever the bond, it is required that the vertical joints in alternate courses should come vertically one over the other. This is quite a simple matter where the walling is straightforward, but where openings occur and at corners in certain bonds, bricks have to be cut to the size required. Thus a brick cut in half is termed a *Half Bat*, and a brick having only three-quarters of the original length is termed a *Three-quarter Bat.*

Closers.—For the same purpose, bricks are cut into halves longitudinally, and again cut into half if necessary transversely, when they are termed *Queen Closers*.

A *King Closer* is a brick cut on the splay from a distance of half its length to a point at the centre of its width.

Other closers are the following: the *Bevelled Closer*, which is cut on a splay starting on one end to a point at the centre of the width of the other end. The *Mitred Closer* is a brick cut on the splay from a distance of one-quarter of the length from the end to be splayed.

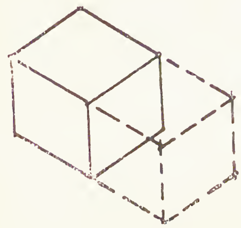


Fig. 8.—Half bat.

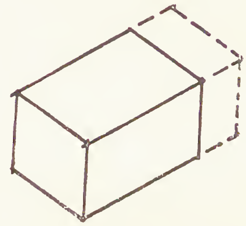


Fig. 9.—Three-quarter bat.

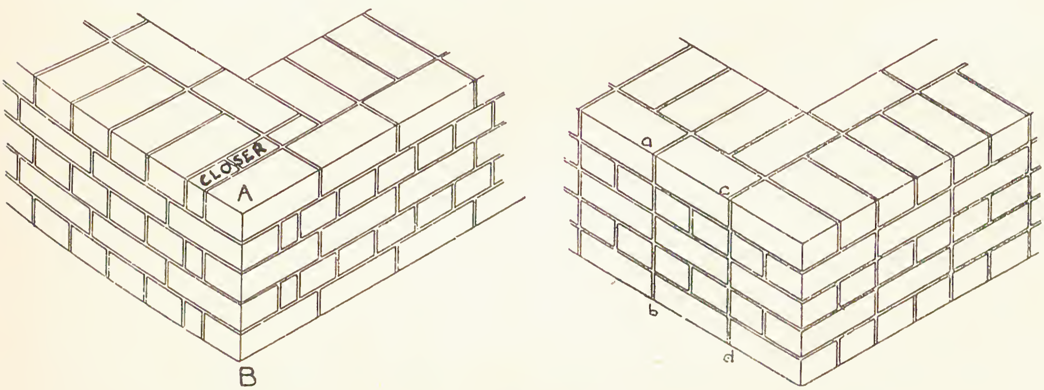


Fig. 10.

Closers prevent straight joints.

Without closers straight joints occur, *ab*, *cd*, etc.

This is also called a *Quarter-mitred Closer.*

A *Half-mitred Closer* is a brick cut on the splay from a point halfway in its length.

Mitred Bats may be of any shape, but the most ordinarily required dimensions are those having half a length on the one side and a quarter of a length on the other, which leaves a bat having half a length on one side and three-quarters on the other.

Bricks for special purposes are made in a variety of shapes, and whereas the bricklayer is accustomed to cut all the foregoing with his trowel,

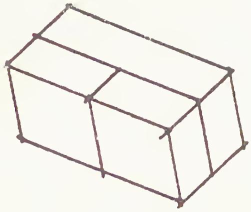


Fig. 11 —Queen closer.

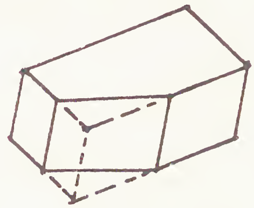


Fig. 12.—King closer.

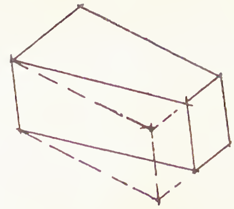


Fig. 13.—Bevelled closer.

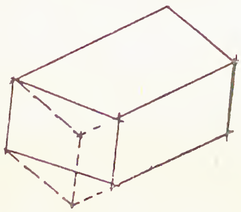


Fig. 14.—Quarter-mitred closer.

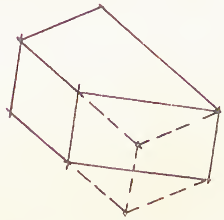


Fig. 15.—Half-mitred closer.

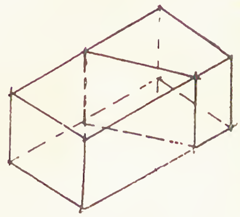


Fig. 16.—Mitred bats.

bricks already pressed into the desired shape are to be obtained for any of the foregoing purposes for the use in Decorative Brickwork, such as, for instance, the construction of brick fireplaces.

SPECIAL-SHAPED BRICKS FROM STOCK

Single Bull-nose is a brick which, when stood on its narrow side, has one of its upper corners rounded.

A Double Bull-nose is a similar brick, having two upper corners rounded.

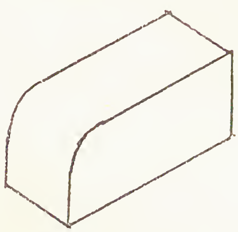


Fig. 17.—Single bull-nose.

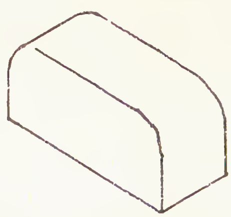


Fig. 18.—Double bull-nose.

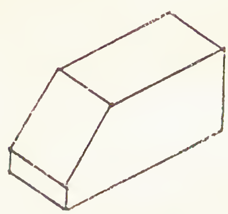


Fig. 19.—Brick-on-edge splay.

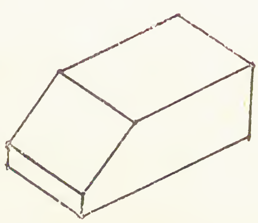


Fig. 20.—Header splay.

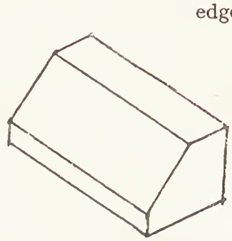


Fig. 21.—Stretcher splay.

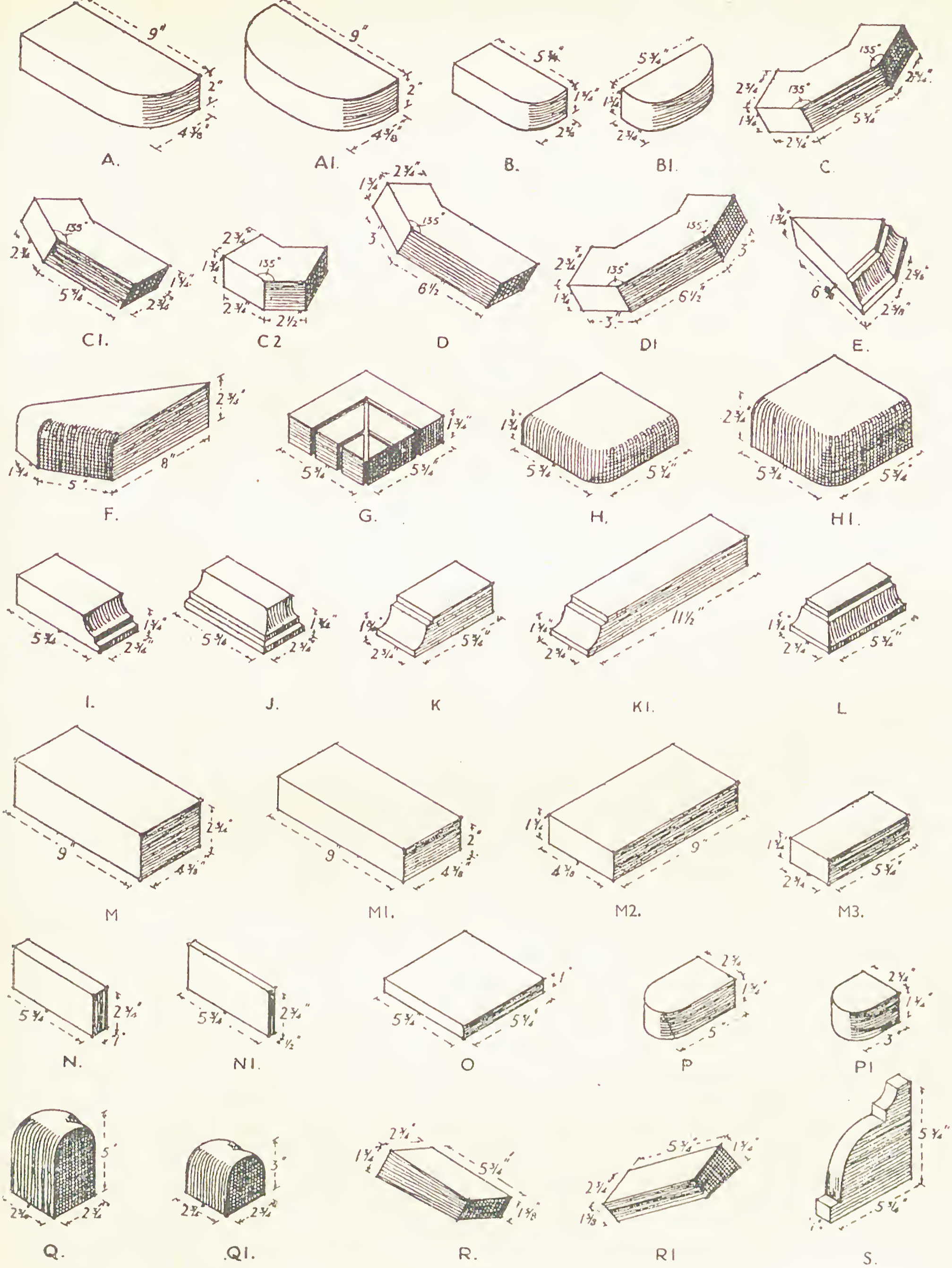


Fig. 22.—Some special bricks.

NAMES OF THE FOREGOING DIAGRAMS

A	Single bull-nose, 9 × 2 × $4\frac{3}{8}$ inches.
A1	Double bull-nose, 9 × 2 × $4\frac{3}{8}$ inches.
B	Single bull-nose, $5\frac{3}{4}$ × $1\frac{3}{4}$ × $2\frac{3}{4}$ inches.
B1	Double bull-nose, $5\frac{3}{4}$ × $1\frac{3}{4}$ × $2\frac{3}{4}$ inches.
C	Full octagon brick, small.
C1	Three-quarter octagon brick, small.
C2	Half octagon brick, small.
D	Three-quarter octagon brick, large
D1	Full octagon brick, large.
E	Moulded return for octagon brick.
F	Bull-nose return for octagon brick.
G	Ribbed hob brick.
H	Hob bull-nose brick, small.
H1	Hob bull-nose brick, large.
I	Short moulded brick.
J	Short moulded return.
K	Short moulded brick.
K1	Long moulded brick.
L	Short moulded return.
M	Large antique brick, 9 × $4\frac{3}{8}$ × $2\frac{3}{4}$ inches.
M1	Medium antique brick, 9 × $4\frac{3}{8}$ × 2 inches.
M2	Small antique brick, long, 9 × $4\frac{3}{8}$ × $1\frac{3}{4}$ inches.
M3	Small antique brick, short, $5\frac{3}{4}$ × $1\frac{3}{4}$ × $2\frac{3}{4}$ inches.
N	Roman tile slip, $5\frac{3}{4}$ × $2\frac{3}{4}$ × 1 inch.
N1	Small tile slip, $5\frac{3}{4}$ × $2\frac{3}{4}$ × $\frac{1}{2}$ inch.
O	Square hearth tile, $5\frac{3}{4}$ × $5\frac{3}{4}$ × 1 inch.
P	Long curb brick, 5 × $2\frac{3}{4}$ × 1 inch.
P1	Short curb brick, 3 × $2\frac{3}{4}$ × $1\frac{3}{4}$ inches.
Q	Long curb return.
Q1	Short curb return.
R	Stretcher arch brick.
R1	Header arch brick.
S	Special arch tile, moulded.

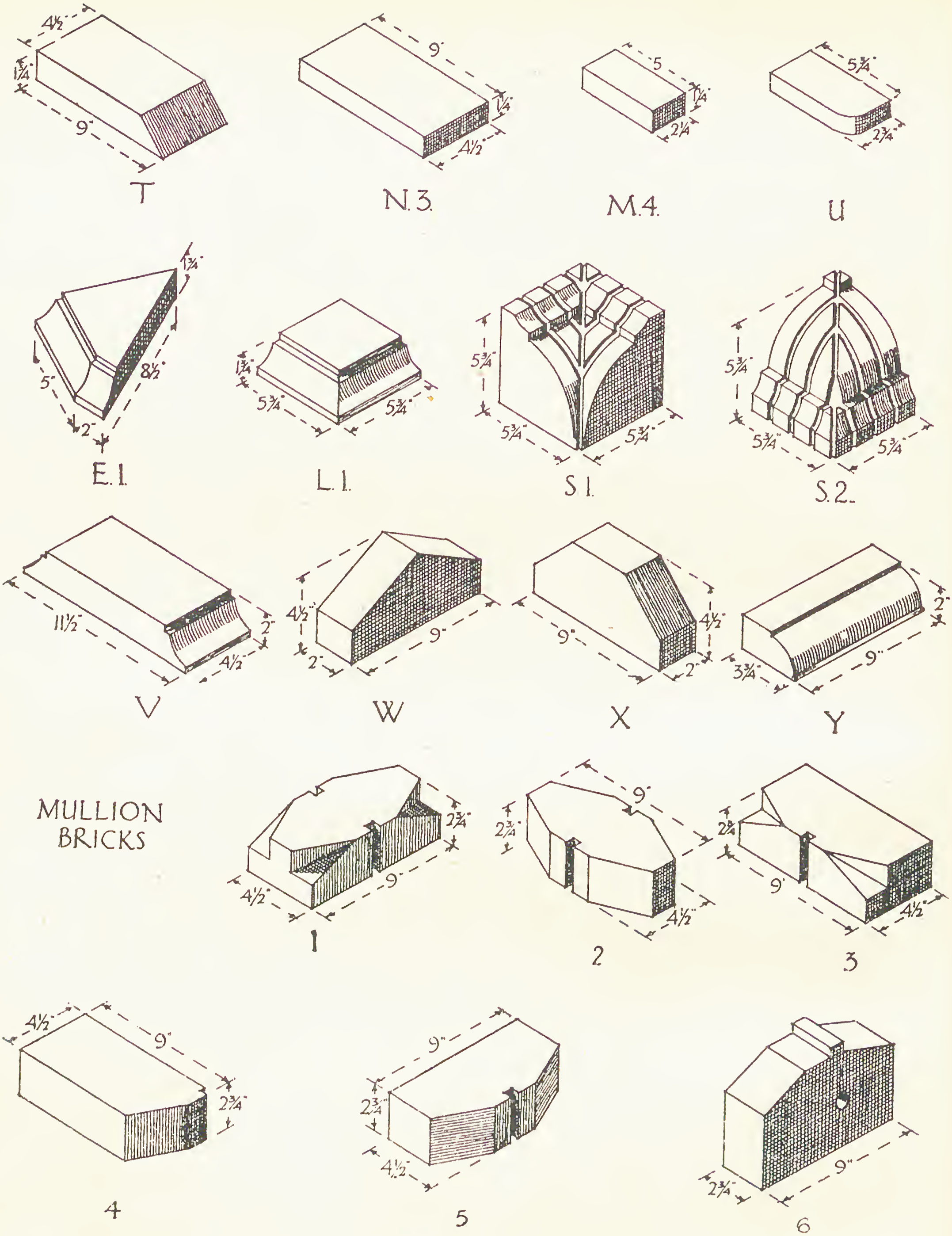


Fig. 23.—More special bricks.

NAMES OF THE FOREGOING DIAGRAMS

T Special herringbone brick.
N3 Long Roman tile, 9 × 4½ × 1 inch.
M4 Hearth brick.
U 1-inch bull-nose brick.
E1 Large moulded return for octagon brick.
L1 Moulded return, large.
S1 Internal angle return for S tile.
S2 External angle return for S tile.
V Special 2-inch double-moulded coping brick.
W V-shaped coping brick.
X Half octagonal coping brick.
Y Special string-course brick.

MULLION BRICKS

1 Mullion return.
2 Mullion brick.
3 Jamb return.
4 Stretcher jamb.
5 Header jamb.
6 Head and sill brick.

A Brick-on-edge Splay is a brick which, when stood on its narrow edge, has one of its upper corners splayed.

A Header Splay is a brick which, when stood on its wider edge, has one of its upper corners cut on the splay, the splay being towards the narrow face.

A Stretcher Splay is a brick stood on its wider edge having one of its upper angles on the long side cut on a splay.

Note.—Any or all of these bricks are used in sills and jambs of windows, door openings, etc.

Other Splayed Bricks.—Bricks are splayed, internally and externally. The *Internal Angle Splay* is a brick which, when placed on its bed, has one of the upper angles on the long side cut at a splay, intercepted by a similar splay cut in the upper face of the brick at a distance of 2 inches from the end. These two splays meet at a bevel, and form a sinking similar to half of a frog. Such bricks are used for the ends of splayed sills to windows. An *External Angle Splay* when placed on its bed has two splays, one on the upper angle on the long face and one on the upper angle on the short face. These bricks are used in such positions as bases to columns. *Coping Bricks* are formed either of *Double Bull-nose, Double Splayed Brick-on-edge*, or *Half Round*. Still further special angle bricks of a variety of sizes and shapes are to be obtained, by the use of which, either by themselves or in combination with each other, almost any desired shape can be formed. For instance, a brick known as a *Full Octagon Brick* is used in fours to complete an octagon. Moulded caps to complete these octagon bricks are also to be obtained. Additional bricks, of different sizes, are supplied to be used in conjunction with these, to increase the diameter of the octagon to any required size.

Hob Bull-nose Bricks, used as pavings to verandahs and to hearths, are flat bricks of $5\frac{3}{4}$ inches square and from $1\frac{3}{4}$ inches to $2\frac{3}{4}$ inches high, having bull-nosed angles on two upper corners.

BONDS

Bricks are disposed in walls in various manners or patterns which are termed Bonds. A wall, consisting of single bricks laid with the lengths of the brick in the length of the wall, is described as being built in *Stretcher* or *Stretching Bond*, and one with the length of the brick laid at right angles to the length of the wall is described as one built in *Heading* or *Header Bond*. The thickness of brick walls is increased in half-brick thicknesses, so that we have wall thicknesses of :

$\frac{1}{2}$ brick	$4\frac{1}{2}$ inches nom. thickness
1 ,, ...	9 ,, ,, ,,
$1\frac{1}{2}$,, ...	$13\frac{1}{2}$,, ,, ,,
2 ,, ...	18 ,, ,, ,,
$2\frac{1}{2}$,, ...	$22\frac{1}{2}$,, ,, ,,

and so on.

In stretcher-bond bricks break joint by $4\frac{1}{2}$ inches, in header bond by $2\frac{1}{4}$ inches.

The two bonds most commonly met with in brick walling are those known as English and Flemish. An English bond consists of a course of stretchers and a course of headers alternately. Flemish bond consists

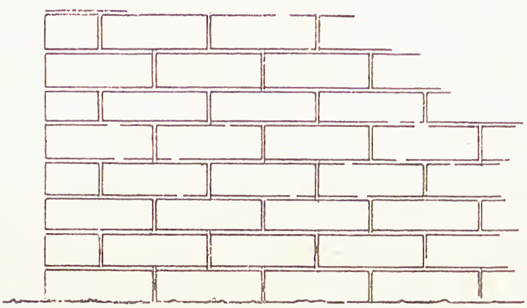


Fig. 24.—Stretching bond.

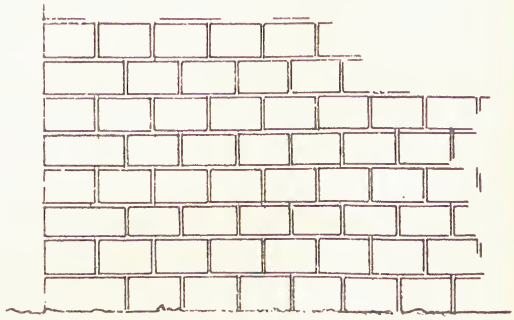


Fig. 25.—Heading bond

of stretchers and headers alternatively in the same course. Both break joint by $2\frac{1}{4}$ inches.

English Bond.—A *One-brick Wall* is a simple construction consisting of one course composed of single bricks laid across the wall, and the course above of two bricks laid along the wall side by side.

A *One-and-a-half Brick Wall* consists of one course all headers with a

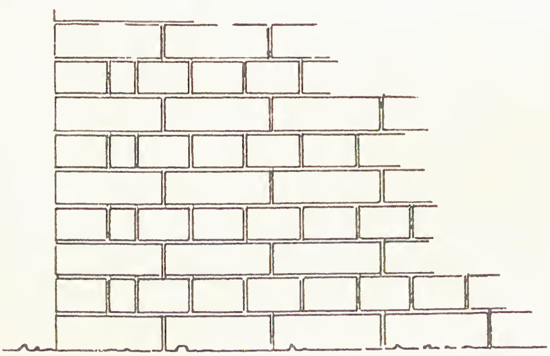


Fig. 26.—English bond.

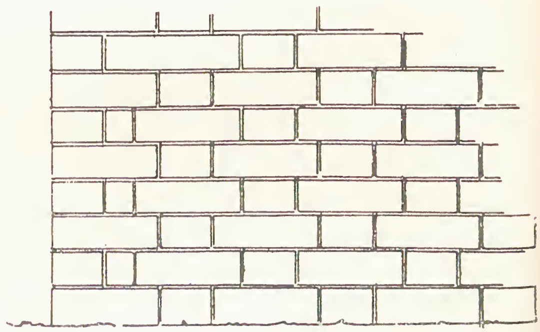


Fig. 27.—Flemish bond.

backing of stretchers, and the course above all stretchers with a backing of headers.

A *Two-brick Wall* consists of one course all headers end to end, and the course above one line of stretchers on the face and one line of stretchers on the internal face filled in between with a line of headers.

A *Two-and-a-half Brick Wall* consists of one course of two headers laid end to end, backed by a stretcher, and the course above formed by a stretcher backed by two headers laid end to end across the wall.

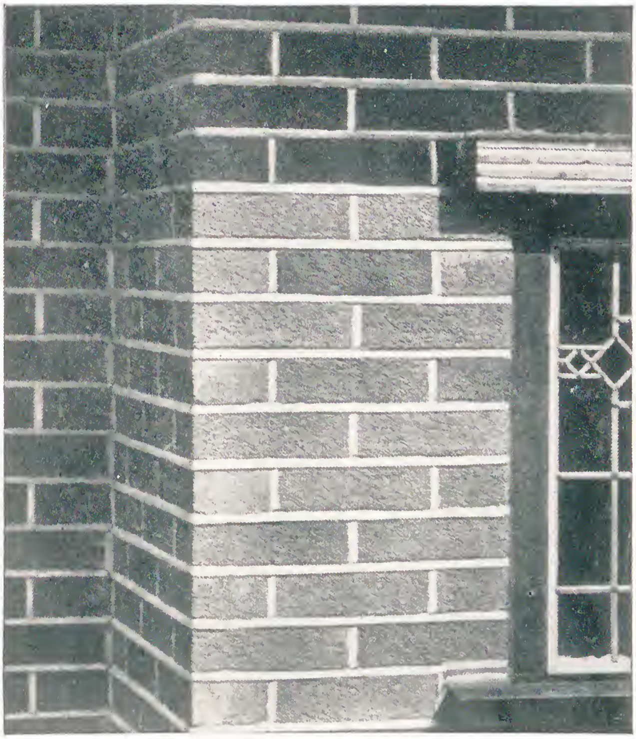


FIG. 28.—STRETCHER BOND.
Closers are not used, the vertical joints being staggered by $4\frac{1}{2}$ inches.

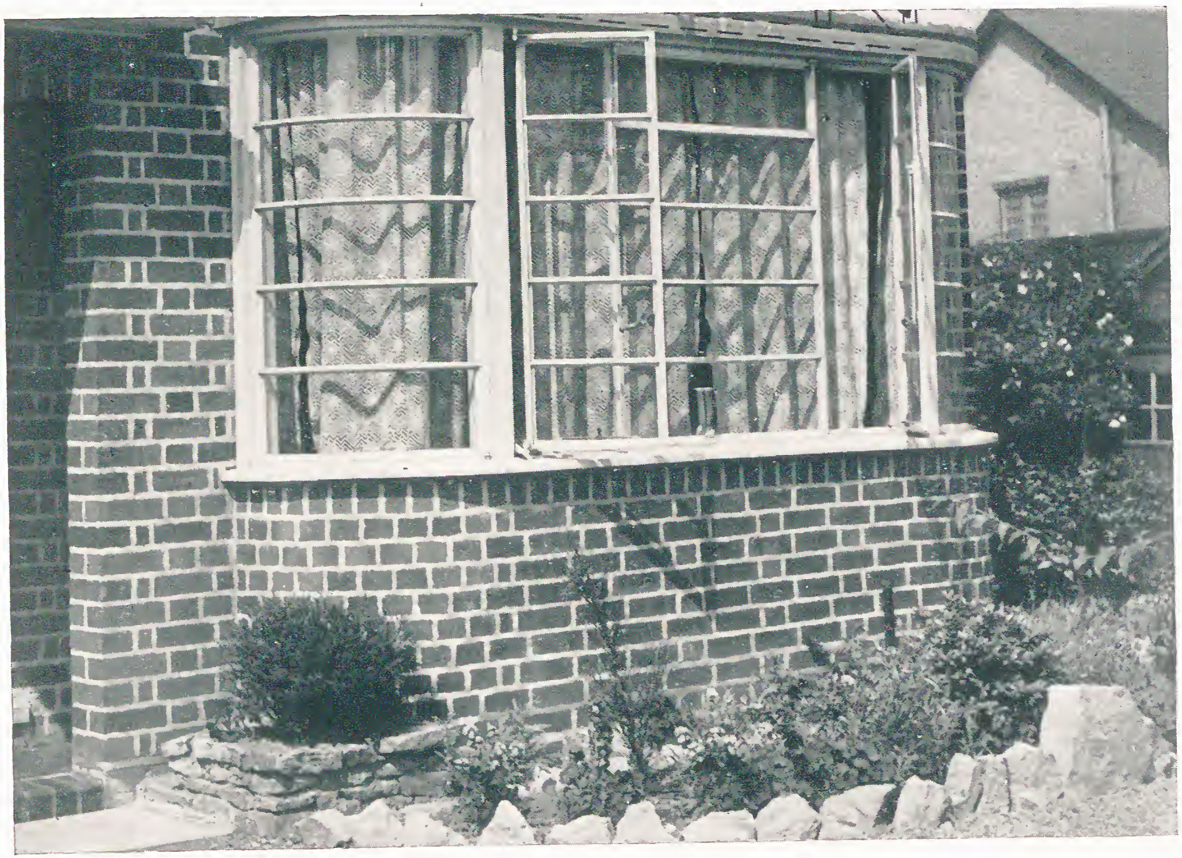


FIG. 29.—HEADER BOND TO CURVED RETURNS OF BAY WITH BRICK-ON-EDGE UNDER SILL.
(Edgar Lucas, A.I.A.A., Architect.)

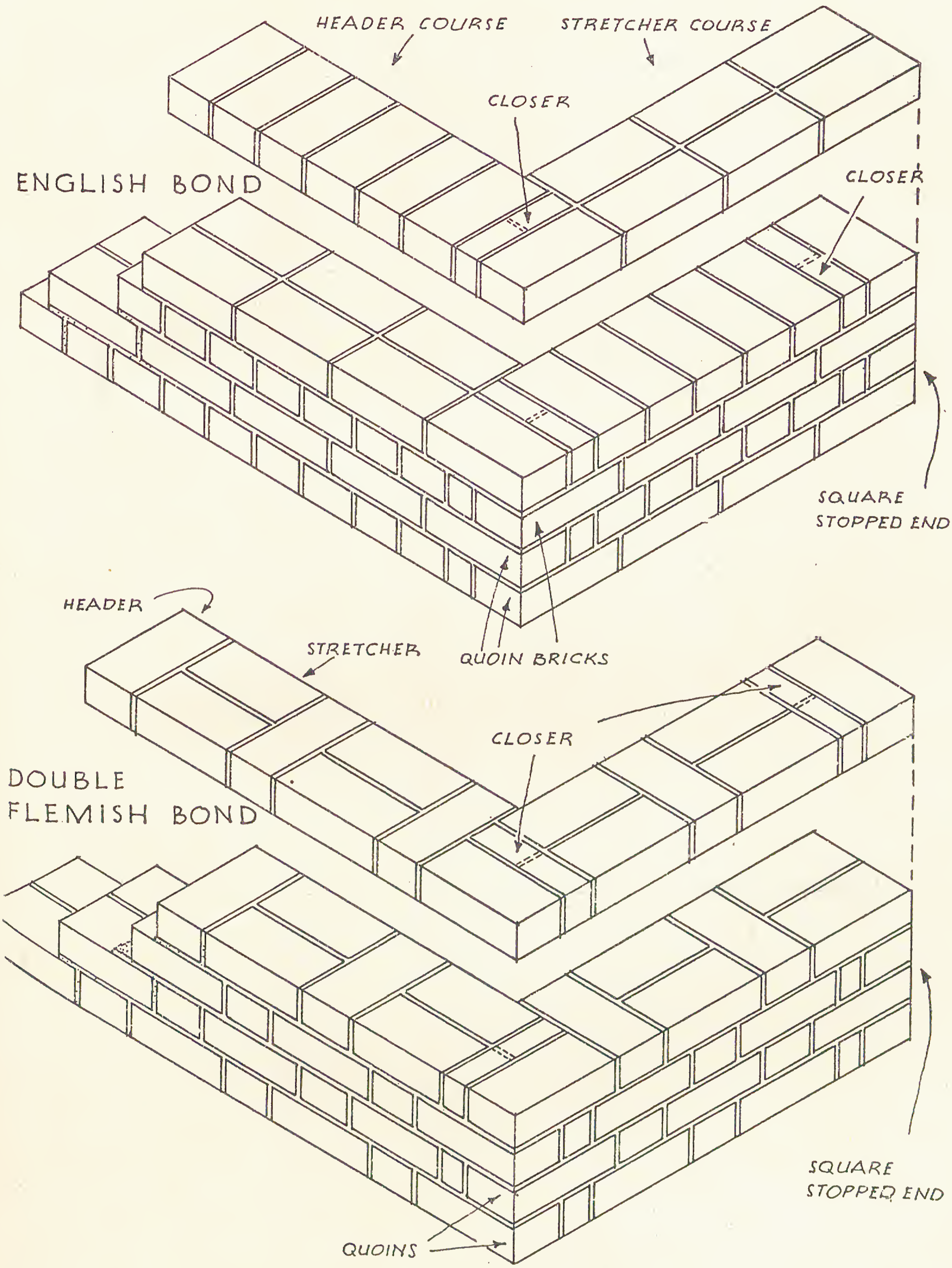


Fig. 30.—English and Flemish bonds: square corners and stopped ends in 9-inch wall.

A *Three-brick Wall* consists of one course all headers, three bricks laid end to end, with the course above composed of an inner and an outer line of stretchers, the internal space being filled in with two courses of headers laid end to end.

The rule in all standard brick walling in English bond is to place the header centrally over each stretcher.

Double Flemish Bond.—Walling, where it is required to show the Flemish bond on both faces, is described as being built in double Flemish bond.

A *One-brick Wall* is formed of a course composed of one header and two stretchers, one header and two stretchers, and so on, alternating with a course consisting of two stretchers, a header, two stretchers, a header, and so on.

A *One-and-a-half Brick Wall* is composed of a header backed by a stretcher, followed by a stretcher backed by a header, the interior space being filled with a bat. This formation is repeated throughout the length of the course. The course above is formed in exactly the same manner, but the header shows on the face of the wall in the centre of the stretcher below.

A *Two-brick Wall* is composed of a course consisting of two headers laid lengthwise across the wall, followed by a stretcher on both faces of the wall, the space between being filled in with three-quarter bats. This formation is followed throughout the length of the course. The course above is formed in exactly the same manner, having the face of the headers placed centrally over the face of the stretchers.

A *Two-and-a-half Brick Wall* is composed of two headers, having a half brick between them, a stretcher along each face, the space in between being filled with three-quarter bats, the header in one course being placed centrally over the stretcher in the course below.

A *Three-brick Wall* is composed of three headers laid along the wall, followed by a stretcher on each face, the interior face being filled in with four stretchers. The course above is constructed in the same manner, having the header placed centrally over the stretcher below.

Single Flemish Bond.—As will have been seen from the formations described, used in laying the courses of walls of varying thicknesses in double Flemish bond, many straight joints occur in the interior height of the walling. Consequently, for walls exceeding one-and-a-half bricks thick, a bond known as single Flemish bond is substituted. This is a wall composed of a Flemish bond facing with an English bond interior.

A *One-and-a-half-Brick Wall*, built in single Flemish bond, is composed of courses formed by an outer face of stretcher and half brick alternately, backed by all headers, having above it a course formed of a header and two stretchers in the thickness of the wall alternately, backed by a course all stretchers.

A *Two-brick Wall* is composed of a course, the outer face of which is formed of a stretcher and half brick alternately, the inner face being

Fig. 31.—ENGLISH BOND—A GOOD MODERN EXAMPLE.
(Photo by Edgar Lucas)

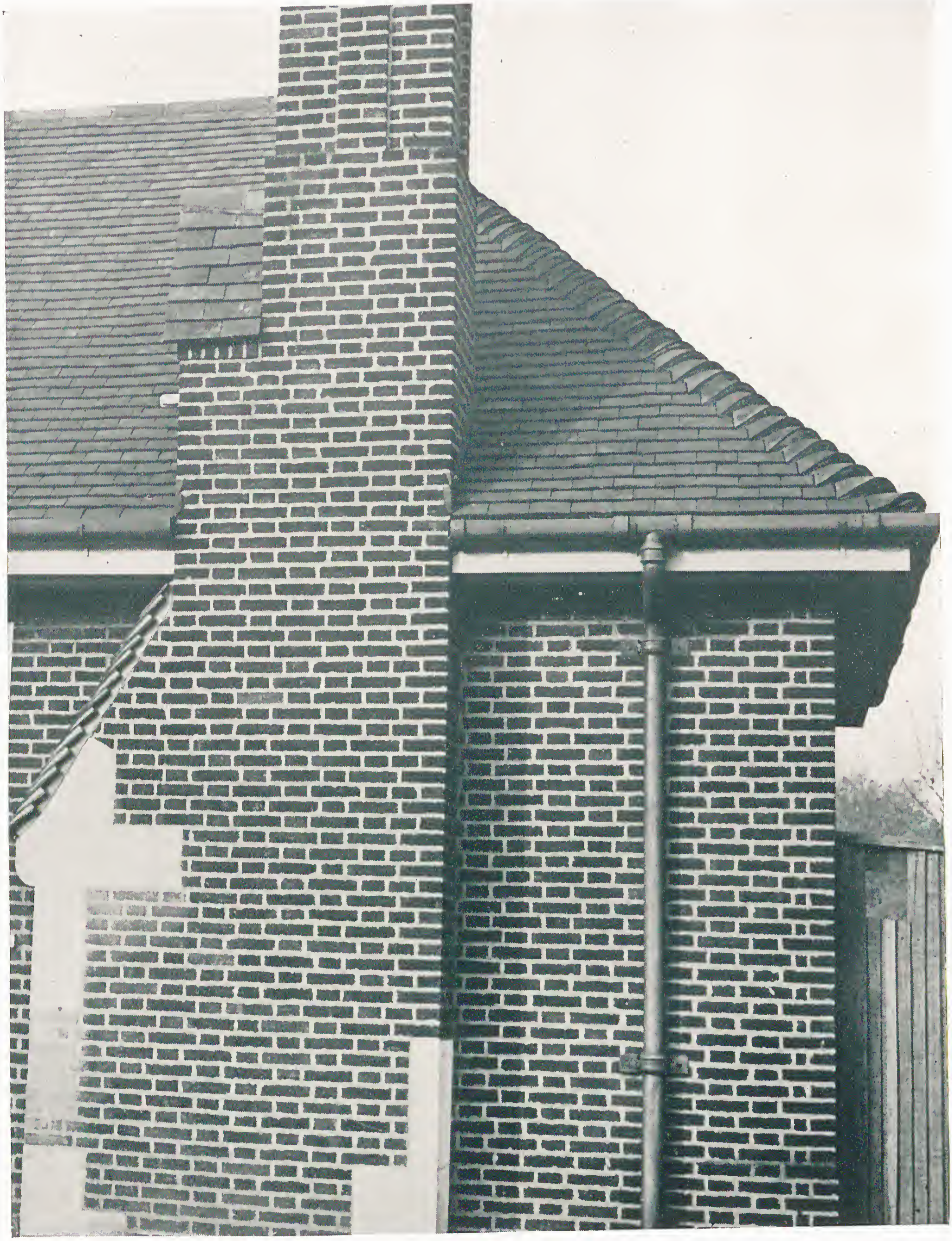


FIG. 32.—FLEMISH BOND IN SANDFACED BRICKS, WITH THICK WHITE JOINTS.
(Photo by Edgar Lucas)

formed of all stretchers, the space in the interior being filled in with all headers. The course above is formed externally of two stretchers and a header alternately, the interior face being all headers.

A *Two-and-a-half Brick Wall* is composed of a course showing externally stretcher and header formed of a half brick, the interior being formed of all stretchers, and the space between all stretchers having straight joints. The course above is formed of a header and stretcher, backed by a stretcher, the interior being all stretchers, the space between being filled in with all headers.

Three-and-one Bond.—One course of headers to three of stretchers. This bond is now widely used, as it is economical in facing bricks and has adequate strength for normal loading conditions. The old name for it is English Garden-wall bond.

Dutch Bond.—Dutch bond is used for strengthening the corners in English bond. As is explained later, instead of terminating the heading courses with a quarter closer next to the quoin header, a three-quarter closer is used, to form the angle of each course of stretchers.

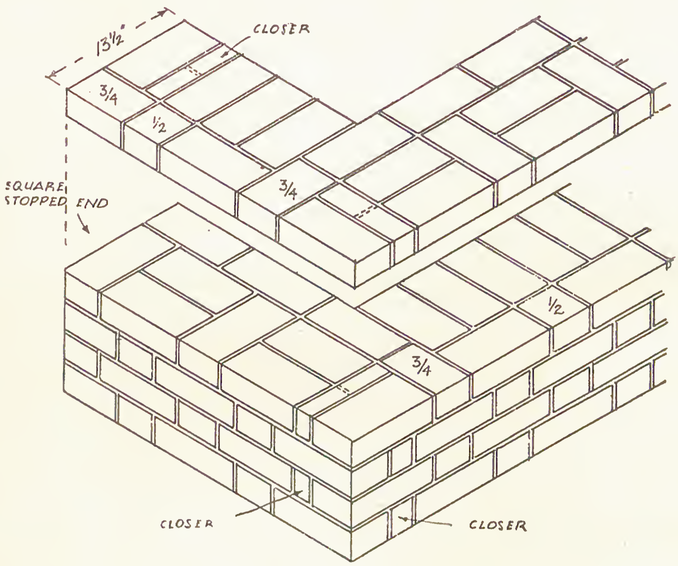


Fig. 33.—Single Flemish bond, square corner and stopped end.

The stretching courses are alternated by the insertion of a header next to the angle closer.

Garden-wall Bond.—There are two kinds: one in which the courses are composed of one header to two, three, four, and sometimes five stretchers laid in each course throughout; and another in which one course of headers is laid to three, four or five courses of stretchers. Flemish Garden-wall bond (Fig. 44) is the best, and is often used for buildings, as it is a fairly strong bond of good appearance.

Herringbone Bond.—Herringbone bond is the name given to the filling in of the interior of a wall of exceptional thickness, the bricks in the interior being laid behind a facing of stretchers, at an angle of 45° both ways from the centre. This bond cannot be used for walls of less than three bricks in thickness. For filling in the angles bats must be cut.

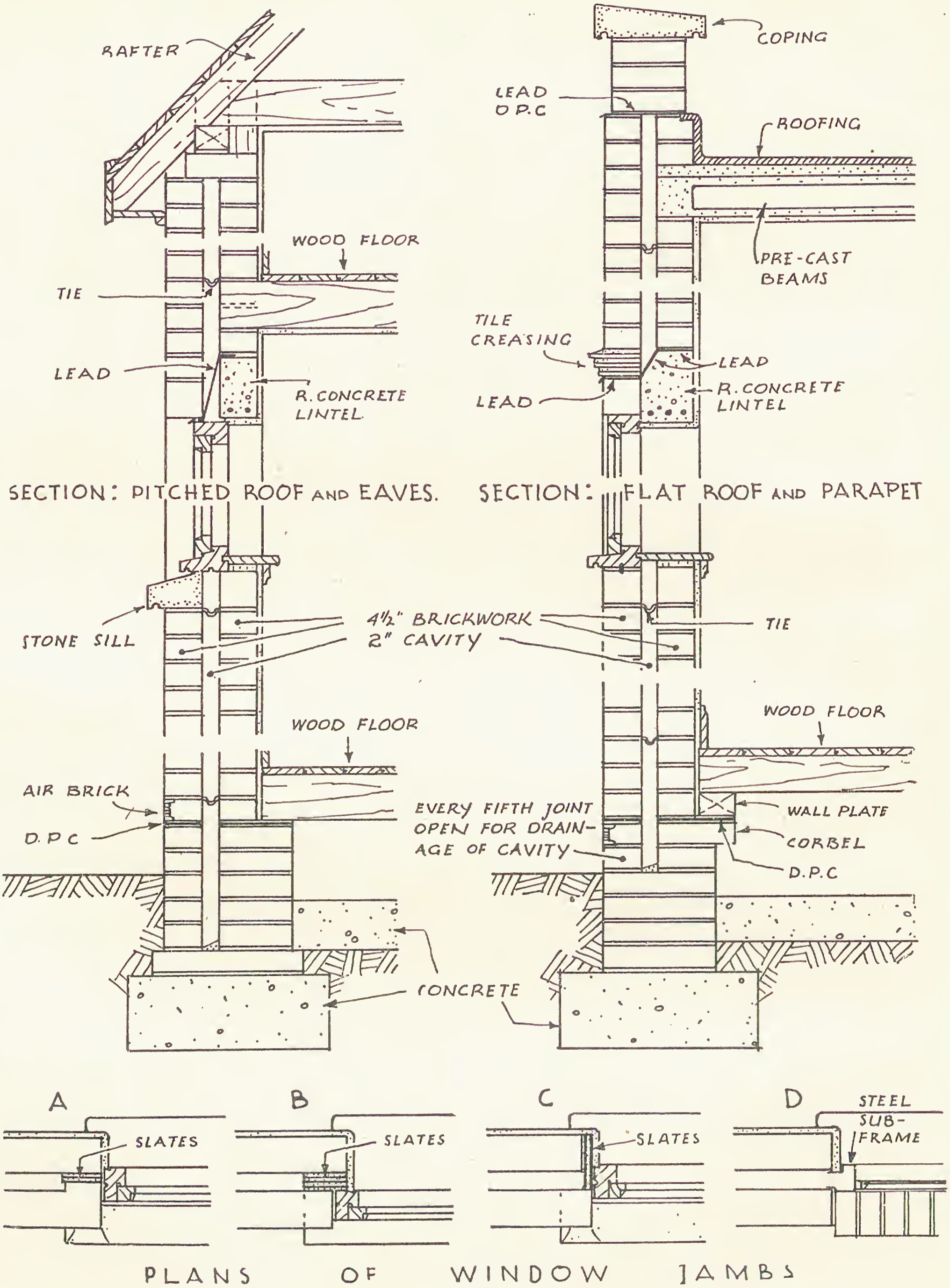


Fig. 34.—Cavity walls.

Raking or Diagonal Bond.—This is another form of the above, in which the filling-in courses are carried diagonally across from one side of the wall to the other, being faced by stretchers.

Both these bonds are useful in forming footings, as they are speedy of construction, and they provide a better bonding of the alternate courses than all headers.

Cavity Walls.—The purpose of forming a wall in two thicknesses having a cavity or hollow space between is to provide a damp-proof wall. Solid walls, however thick, may absorb damp if rain continues long enough.

Hollow walls are built in varying thicknesses when the following bonds are used. An 11-inch wall formed of two $4\frac{1}{2}$-inch walls with a 2-inch cavity may be formed of two walls of all stretching bond; or the inner wall may be built in stretching bond and the outer in Flemish bond, when the header will require to be cut in half. A $15\frac{1}{2}$-inch hollow wall, having a $4\frac{1}{2}$-inch outer wall and a 9-inch inner wall, has the outer wall laid in stretching bond, and the inner wall in English bond; or alternatively, it may have the outer wall in Flemish bond, the headers being cut as before, and the inner wall in English bond, in which one course will be composed of two stretchers side by side, the course above consisting of all headers.

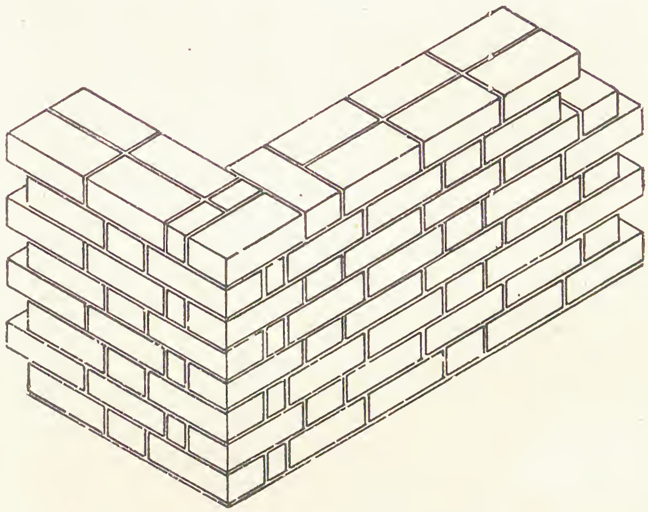


Fig. 35.—Flemish garden-wall bond.

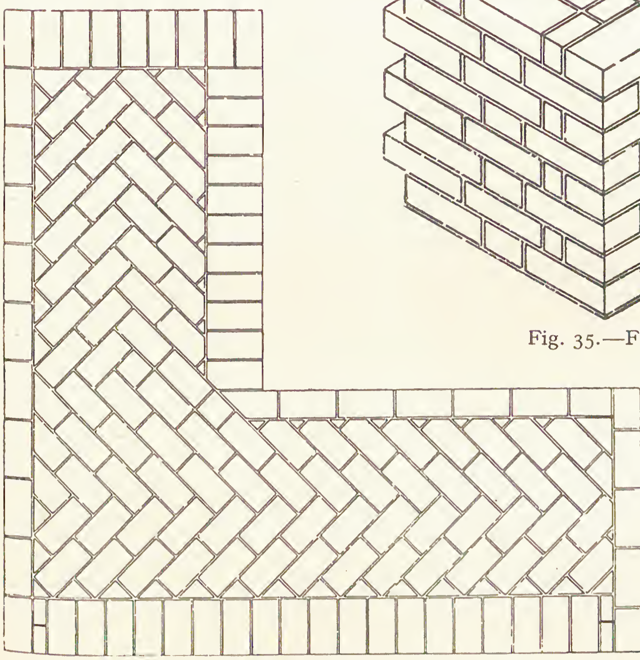


Fig. 36.—Herringbone bond.

Wall Ties.—To increase further the stability of hollow walls, ties are built in from the outer to the inner wall. Though the main object of these ties is to increase stability, it will be clear that they must interfere

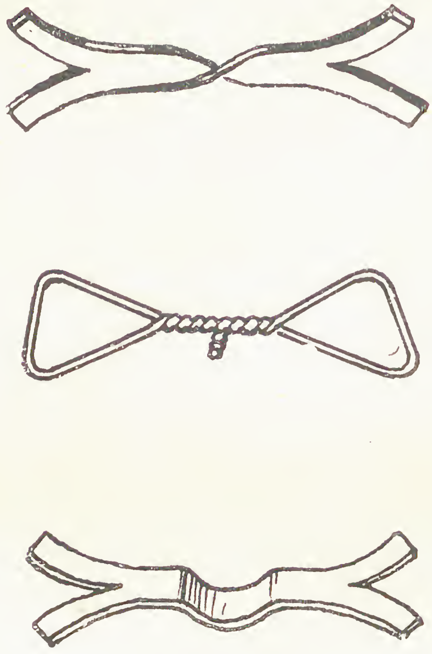


Fig. 37.—Metal ties.

as little as possible with the cavity. They are placed at distances of about 3 feet apart horizontally, and 1 foot 6 inches vertically. These ties are formed of rust-proofed metal, or glazed stoneware, and, whichever type is used, it is essential that they shall prevent damp creeping from the outside wall to the inner wall.

Metal ties are of various designs, and one made of a length of steel is twisted at its centre and split at its ends, which are turned downwards. They are about 7 inches long.

Other Metal Ties are of *Iron Wire,* formed into two triangles, the bases of which are built into the brickwork. These last two ties are $8\frac{1}{2}$ inches to 6 inches in length, the greater length being required to give a stronger anchorage into the joints.

The stoneware wall ties may be either formed of glazed stoneware or unglazed. The *Glazed Stoneware Tie* is so formed that one end is provided with a $2\frac{1}{4}$-inch level base to be built into one course in the outer wall and the $4\frac{1}{2}$-inch level base for building into the inner wall at the level of the course above, that in the outer wall, the portion bridging the cavity, being curved to rise the necessary $2\frac{3}{4}$ inches. They are now rarely used, as they afford a ready lodgment for mortar droppings.

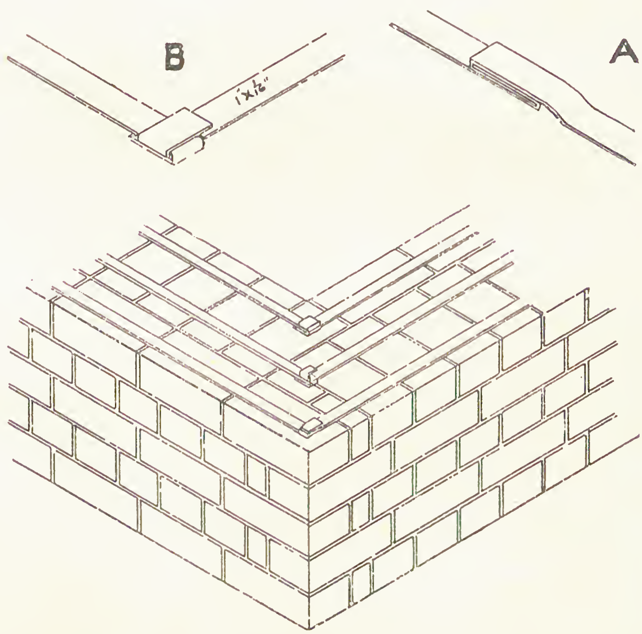


Fig. 38.—Hoop-iron reinforcement.

Perhaps the most important feature of the hollow wall which is often overlooked is that the hollow must be continuous from top to bottom, and must extend below the d.p.c., which must be in two thicknesses, and all round the building, except where openings occur. Continuity of cavity is necessary where a chimney stack occurs on the outside of a wall, making a projection. The outer wall and cavity must be continued around the chimney stack in just the same manner as to the main walling to the building.

Where openings occur in hollow walls, the cavity may be finished by placing a vertical d.p.c. of slates in cement.

Brick-on-edge Bonds.—In old work, though rarely in new, walls are sometimes built in brickwork only 3 inches thick. This thickness is obtained by building the bricks on edge, so that they show courses $4\frac{1}{2}$ inches on the face.

A form of bonding for a double wall, consisting of bricks on edge, is known as the *Rat-trap Bond.* This consists of an inner and an outer wall with voids, crossed by 9-inch headers on edge.

A Brick-on-edge Wall forms a suitable backing for vertical tile hanging, as it gives the necessary gauge and key.

Strength of Bonds.—The strongest bond is the *English Bond*, as the tie is afforded by its formation, lengthwise and across the wall. The *Flemish Bond* is probably more used on account of its pleasing appearance than for its strength. The *Garden-wall Bonds* provide the least strength of tie, and are only suitable for walls of moderate height. *Three-and-one Bond* is considered to be strong enough for normal loading conditions.

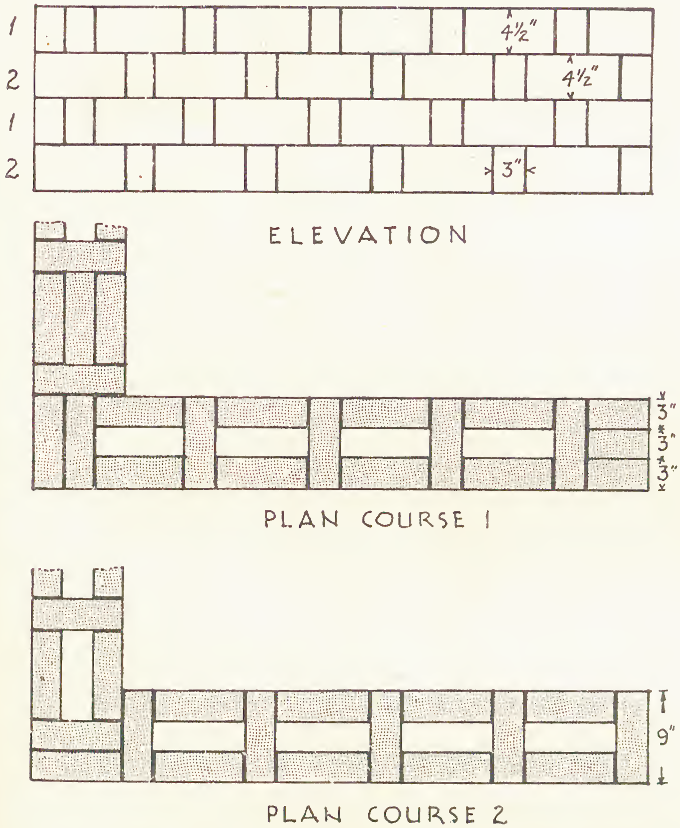


Fig. 39.—Rat-trap bond.

REINFORCED BRICKWORK

Plain brickwork is well able to withstand direct compression, but has little strength against side thrust and sheer stress. In this it resembles plain concrete.

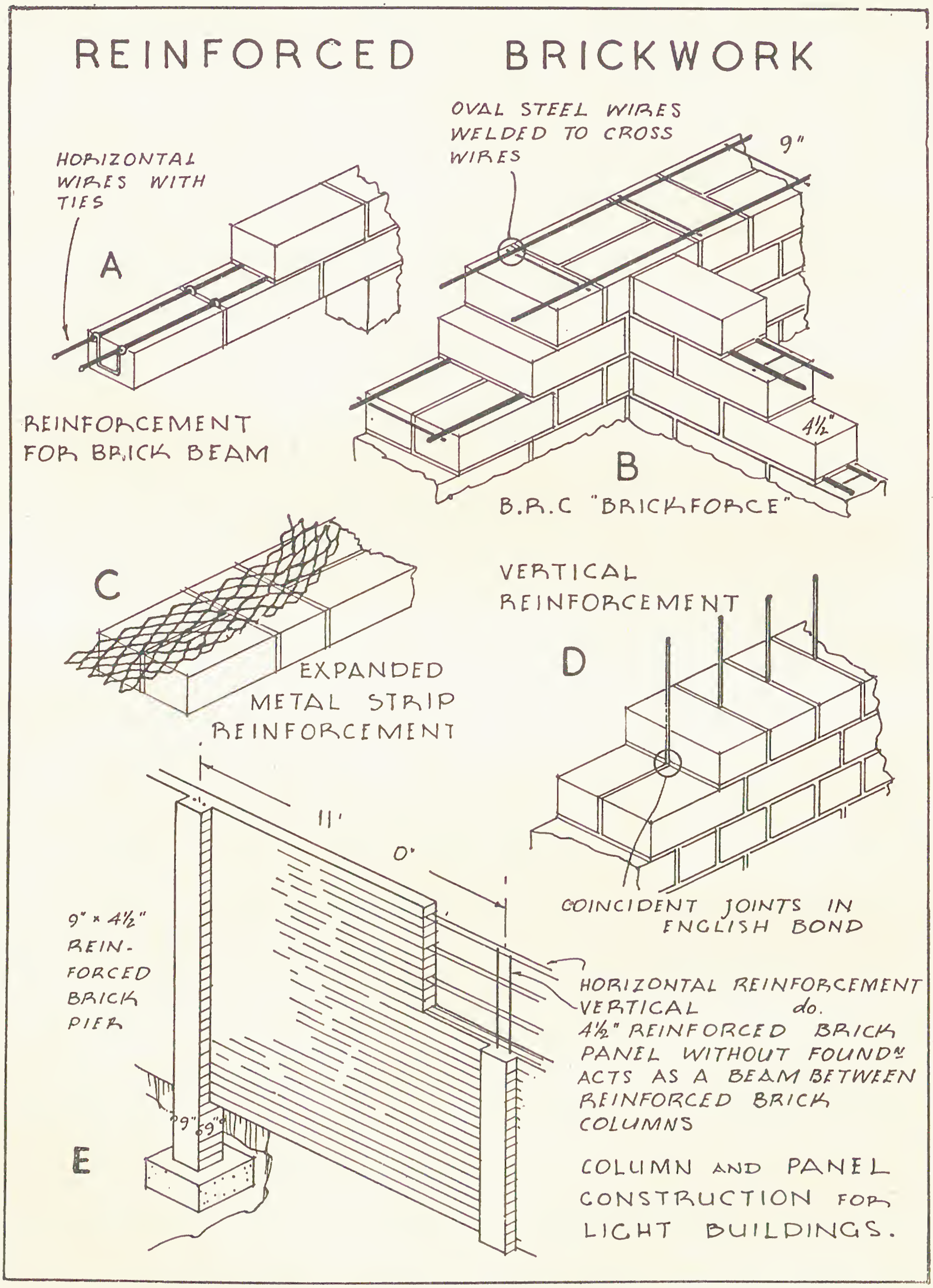


Fig. 40.—Reinforced brickwork.

Steel has great strength in tension, and it can be used to reinforce brickwork in the same way as it is used to reinforce concrete. Thus, a reinforced brick wall will withstand horizontal pressure or diagonal thrusts within its designed capacity. Brickwork can also be reinforced to act as a beam or lintel. One useful application of this is to allow brickwork to carry its own weight from pier to pier without intermediate supports, as shown in Figs. 40 and 41.

An early form of reinforcement is shown in Fig. 38. This consists of hoop iron embedded in the horizontal joints. It is now more convenient to use one of the proprietary mild-steel strip reinforcements. These are of two types: expanded metal and welded wire.

Expanded Metal is supplied in coils for this purpose, in widths of $2\frac{1}{2}$ inches, 7 inches, and 12 inches, to suit wall thicknesses of $4\frac{1}{2}$ inches, 9 inches, and $13\frac{1}{2}$ inches respectively. In most work it is laid in the horizontal bed joints of every second or third course.

Welded Wire Mesh.—This consists of two horizontal wires held at the correct distance apart by cross wires. In B.R.C. "Brickforce" oval wires are used, this section lying flat on the bed and taking up the minimum thickness. For $4\frac{1}{2}$-inch walls the mesh consists of two strands of wire 3 inches apart with cross wires welded to them at intervals of 12 inches. For 9-inch walls the mesh consists of two strands of wire 6 inches apart with cross wires at intervals of 12 inches.

Steel Rods.—Mild-steel rods can be used for both horizontal and

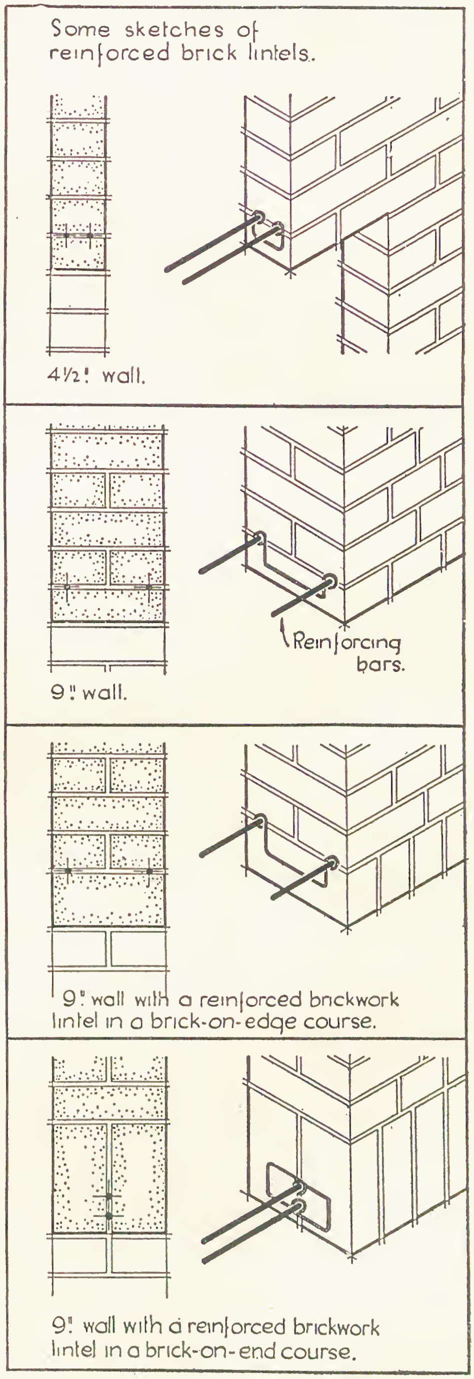


Fig. 41.—Reinforced brick lintels with mild-steel rods and stirrups in joints.

vertical reinforcement. Fig. 41 illustrates the use of rods to form reinforced brickwork lintels. Wire stirrups should be used to "suspend" the soffit course of bricks.

Vertical Reinforcement.—Steel rods or wires can be passed through the vertical straight joints of brick walls, as shown in Figs. 40 and 43, in both English and Flemish bonds, though in English bond the straight joints are no more than intersections.

Mortar.—This should be a strong cement mortar of 1 part Portland cement to 2 or 3 parts clean sand. The bricks should be partially soaked, and great care taken to fill all joints. In hot weather the work should be covered to prevent too rapid drying out, which tends to cause excessive shrinkage.

A form of internal bonding which is really metal reinforcing consists of stretching strips of hoop iron along the courses of the wall spaced one at the centre of each half brick, and built into the joints of the brickwork, Fig. 38, the joints in the length of the hoop iron being formed with a welt lap, A, and that between a cross wall and a main wall being a hooked joint, B, the ends of the reinforcement being woven under and over the reinforced strips in the main wall.

It is perhaps in the bonding of cross walls to main walls that the greatest usefulness of this form of bonding is experienced. The hoop iron should be well galvanised, or tarred and sanded (see Fig. 38).

Another form of metal reinforcement is effected by the use of one or other of the expanded metals.

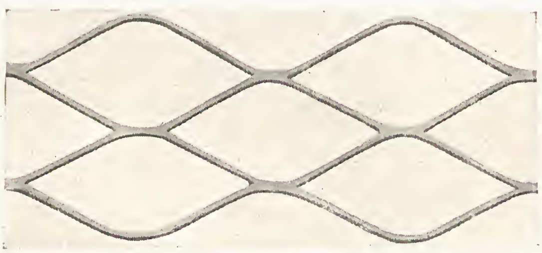


Fig. 42.—A portion of "Exmet."

Exmet is supplied by the Expanding Metal Company, Ltd., in widths of 2½ inches, 7 inches, and 12 inches, in coils, and in bundles of flat strips of any required length. When it is uncoiled it lies flat, having no tendency to recoil. It can be cut easily with a pair of hand shears. The metal is pressed out into diamond-shaped meshes, of from 8-inch to 3-inch mesh, in thicknesses from 27 inches to 12 inches gauge.

It has been found that the coiled material is preferable, as it occupies less space in storing, and is more conveniently handled, not only in transport, but on the job.

BRICKLAYING

Practical experience under a skilled instructor is the only way to learn bricklaying, but a brief outline of sound practice will be useful to some readers.

The two operations in bricklaying which call for dexterity are: first, picking up the mortar with the trowel and placing and spreading it on the wall by skilful wrist movements ; second, the correct placing of the brick with moderate hand pressure to place it level on the bed. Any slight error is corrected by tapping the brick with the trowel handle.

Soaking Bricks.—If bricks are dry when laid, they rapidly absorb the moisture in the mortar, resulting in shrinkage of the mortar and the development of fine cracks which allow damp to creep through the joints. Bricks should not be thoroughly soaked, but they should be immersed for a few minutes in clean water. In hot dry weather the brickwork should be covered with building paper or clean sacks to retard the drying out for at least a week.

The Corners are built up for a few courses before the main part of the wall is proceeded with. The corner is carefully set out with the bricklayers' square, the faces of the quoins tested with the plumb rule, and the beds with straightedge and spirit-level.

With the two corners built up, the courses between can be built up. To keep these courses truly level the bricklayers' line and pins are used. The pins are placed in cross joints so that the line is level with the top of the quoin bricks and just clears the face of the bricks. If the line is long, a tingle is set up in the middle to prevent sagging.

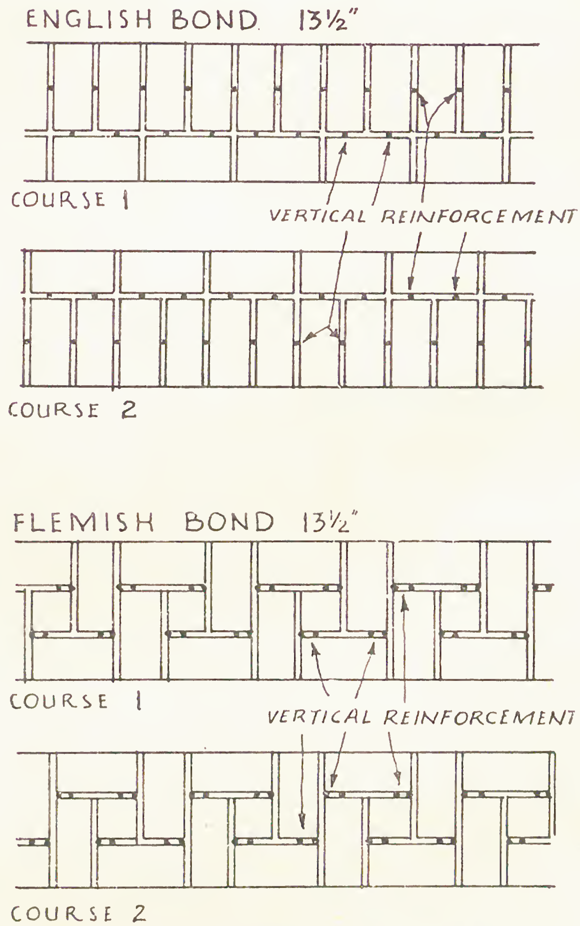


Fig. 43.—Reinforced brickwork. Plans of 13½-inch walls, showing positions of vertical reinforcement in straight joints.

Perpends.—Care must be taken to keep the perpends (vertical face joints) in a straight vertical line, so that perpends in alternate courses are in line. A small steel square should be used for this purpose.

The Gauge Rod should be used to give an indication of the correct rise of courses. This is held truly vertical just clear of the wall face.

The following table from *The Architect's Journal Library of Planned*

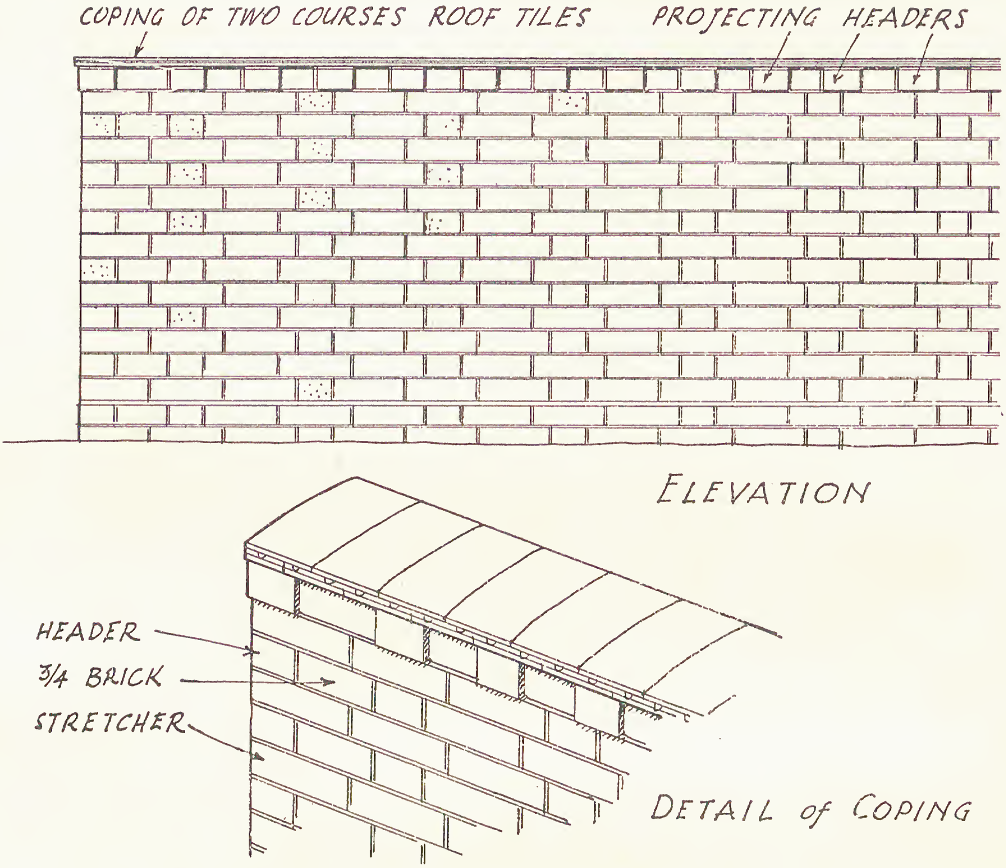


Fig. 44.—Flemish garden-wall bond.

Information is useful in marking out the gauge rod. It gives the rise up to ten courses for various brick and joint thicknesses.

TABLE OF HEIGHTS of brick coursing with various joints

No. of Courses.	2-inch Brick.			2⅝-inch Brick.			2⅞-inch Brick.		
	Thickness of Joint.			Thickness of Joint.			Thickness of Joint.		
	⅜ in.	½ in	⅝ in	⅜ in.	½ in.	⅝ in.	⅜ in.	½ in.	⅝ in
1	2⅜ in.	2½ in.	2⅝ in.	3 in.	3⅛ in.	3¼ in.	3¼ in.	3⅜ in.	3½ in.
2	4¾ in.	5 in.	5¼ in.	6 in.	6¼ in.	6½ in.	6½ in.	6¾ in.	7 in.
3	7⅛ in.	7½ in.	7⅞ in.	9 in.	9⅜ in.	9¾ in.	9¾ in.	10⅛ in.	10½ in
4	9½ in.	10 in.	10½ in.	1·0	1 0½	1·1	1·1	1·1½	1·2
5	11⅞ in.	1·0½	1·1⅛	1·3	1·3⅝	1·4¼	1·4¼	1·4⅞	1·5½
6	1·2¼	1·3	1·3¾	1·6	1·6¾	1·7½	1·7½	1·8¼	1·9
7	1·4⅝	1·5½	1·6⅜	1·9	1·9⅞	1·10¾	1·10¾	1·11⅝	2·0½
8	1·7	1·8	1·9	2·0	2·1	2·2	2·2	2·3	2·4
9	1·9⅜	1·10½	1·11⅝	2·3	2·4⅛	2·5¼	2·5¼	2·6⅜	2·7½
10	1·11¾	2·1	2·2¼	2·6	2·7¼	2 8½	2·8½	2·9¾	2·11

FIG. 45.—WALL AND PIER IN FLEMISH BOND WITH STONE COPING.

FIG. 46.—THIN SANDSTOCK FACINGS WITH MOULDED COPING BRICKS TO PARAPET.

(Both photos by Edgar Lucas.)

In the above table the dimensions are taken from the bottom of the joint below the first brick to the top of the brick, i.e. the dimensions include an equal number of bricks and joints.

Setting Out.—To set out positions and levels of walls, floors, etc., two starting-points are needed : the building line and the datum level.

Usually, the local authority defines a building line parallel with the road frontage, and building is not allowed in front of this line. The local surveyor should either set out this line by pegging or approve the line as set out by the contractor. By reference to the plans the positions of walls can then be set out.

It is often convenient first to place pegs at all outside wall corners and junctions. These should be checked and approved by the clerk of works or architect. Profile boards (see Vol. I, Chapter 6) are then set up to indicate the width of foundations. The excavators and bricklayers can then work from these profiles.

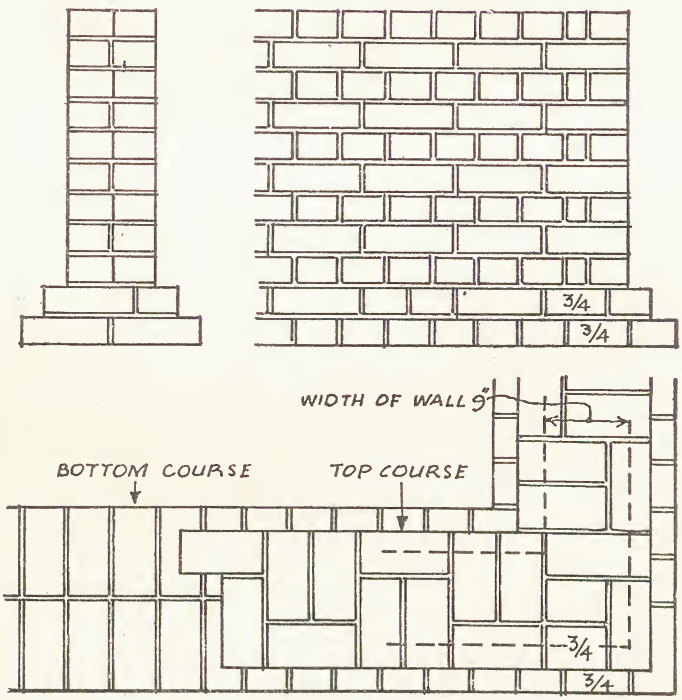


Fig. 47.—Footings for 9-inch wall.

To set out the outline of the outer walls, start at one outside corner with a pair of pegs, driving the starting peg into the ground so that one side of it is in line with one wall, then drive in the second peg so that one side of it is in line with the wall round the corner. Secure the line to the first peg, carry it along and fix it to a third peg placed in the correct position. Pegs should be fixed at least 2 feet 6 inches from the wall corners so that they will not be disturbed. The bricklayers' square is used to set the lines at true right angles. For squint corners an angle templet should be made. The profile boards giving wall and foundation widths can then be set up at each corner. Lines can then be run from the profile marks to give trench and wall widths.

Lengths should be measured with a steel tape, keeping it level and stretching it just taut. Lengths should be in multiples of half brick plus a joint to allow the wall to be bonded without cutting.

Levels.—A datum level should be indicated on the drawings (see Vol. I, Chapter 6). This may be a mark on an adjoining building, the top of the road kerb at a certain point, or a near-by Ordnance Survey bench mark. The levels of the foundations, damp-proof course, ground floor, etc., can then be fixed by reference to this datum, using the dumpy level or the bricklayers' spirit level and straightedge to transfer the datum to the work. It is sometimes convenient to level a datum peg near the work, setting it in concrete so that it cannot be disturbed.

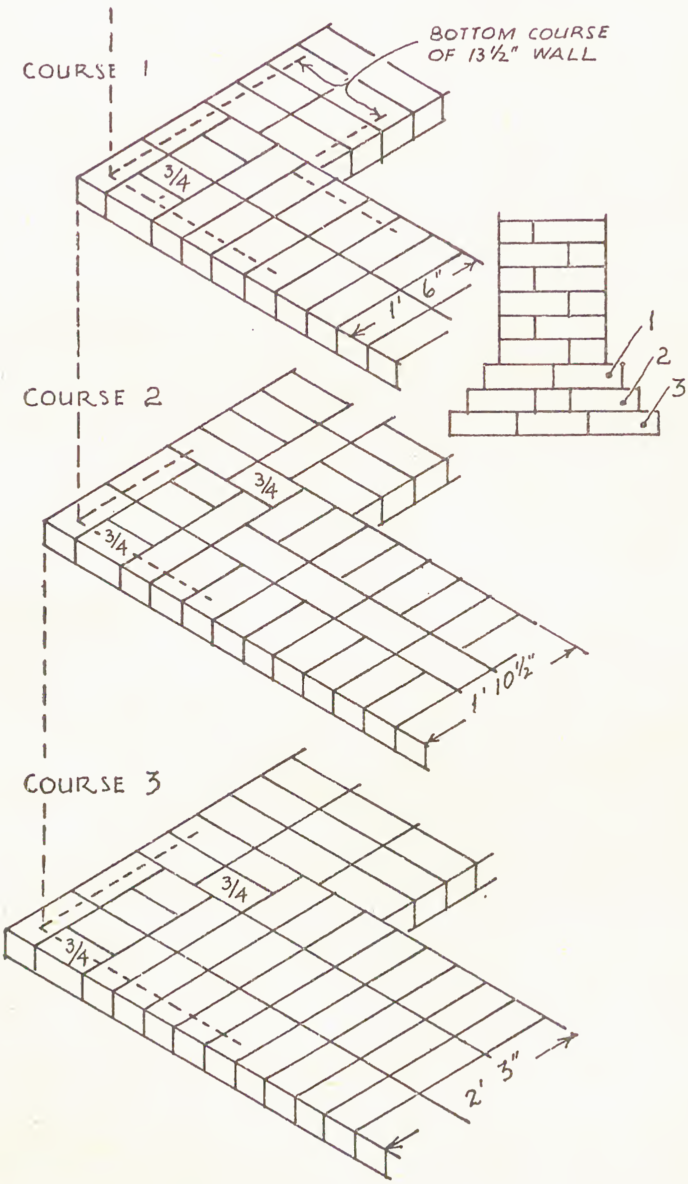


Fig. 48.—Footings for 13½-inch wall.

Frost.—In low temperatures the setting action of mortars is retarded until near freezing-point it ceases. Temperatures at or near freezing-point thus destroy the strength of mortar. Special precautions can be taken to enable urgent work to be done in low temperatures, but it is so difficult to ensure protection that generally bricklaying should be suspended when the temperature falls below 40° F. Stoves or braziers may be placed near the mixing-point and the work. As the work is done it should be covered with several layers of clean sacking or sacks stuffed with straw.

Frost also has a destructive effect on soft mortars and bricks after the mortar has set. This is caused by the absorbed water expanding as it freezes and damaging the bricks and mortar by internal pressure. With mortars and bricks of normal strength this trouble is not likely to occur.

BRICKLAYER'S TOOLS

These comprise two trowels, the *Bricklayer's* and the *Pointing Trowel.* the latter being smaller than the former.

The *Line and Pins*, already referred to.—These consist of two steel flat-shaped pins, to each of which is attached a ball of twine, half of which is rolled round each pin when not in use. The pins are pushed into the joints of the brickwork at the angles, rising 3 inches at a time.

The *Spirit Level.*—Though the line is used by the bricklayer in laying his courses level, an additional check is required from time to time, and this is supplied by a spirit level. This may be a spirit level of the ordinary type, or it may be combined in the form of a *Plumb Rule.* This enables the level to be checked over a longer area, as it consists of a piece of pine 4 inches wide by 4 feet to 5 feet in length. It is also used for checking the exactness of the perpendicular of the wall, having an opening cut in one end, in which hangs a *Lead Bob*, attached to the other end of the plumb rule by a string. The side of the plumb rule has a line drawn on it from the point of suspension of the bob to the opening in which the bob hangs, and when the line attaching the bob lies over the line on the side of the rule, the wall is vertical. The lead weight and the string are known as the *Line and Bob.*

A *Short Straightedge*, of about 3 feet in length, having 3-inch divisions marked on it, serves as a guide to the levels of the courses, enabling these to be checked at any time. This tool is used mostly when setting out the corners of the building. These are set up first and the spaces between are then filled in to the level given by the line, and checked, as has been explained, by the spirit level.

For forming corners and angles an instrument known as the *Square* is used. This is generally of steel, having two arms at 90°, and inches marked on each. The length of the arms is generally 12 inches. It is also used for squaring openings for doors and windows.

The other tools used by the bricklayer are mainly those for cutting the brick when required and for pointing.

The *Bolster* is really a form of cold chisel having a blade of about 5 inches wide, and is used for cutting closers.

The *Cold Chisel* is an octagonal length of steel sharpened at one end and is generally used for cutting away brickwork already built.

The *Club Hammer.*—For use with these two chisels, a short-handled hammer, having an oblong steel head, $2 \times 2 \times 4$ inches, is used.

The *Bricklayers' Hammer* is formed of a short wooden handle fitted into a metal head similar to a short pick, having one end pointed and the other squared.

The *Scutch and Blade* is used for finishing up cut bricks, after they have been cut roughly by the bolster. It consists of a wooden handle which is fitted to a blade and wedge.

The tools used in pointing may be considered together, as they are used in conjunction with one another. They consist of the *Pointing Trowel*, the *Pointing Rule*, and the *Frenchman*. The trowel is from 2 inches to 6 inches in length. The rule is 4 feet long and 3 inches wide, feather edged on one side, having pieces of wood $\frac{1}{2} \times 3$ inches to raise it from the face of the brickwork. The purpose of this is to keep the brickwork clean when the joint is trimmed in pointing with the trowel. The Frenchman, also known as the *Jointer*, is a form of knife fitted to a wooden handle, and is used for cutting the joints.

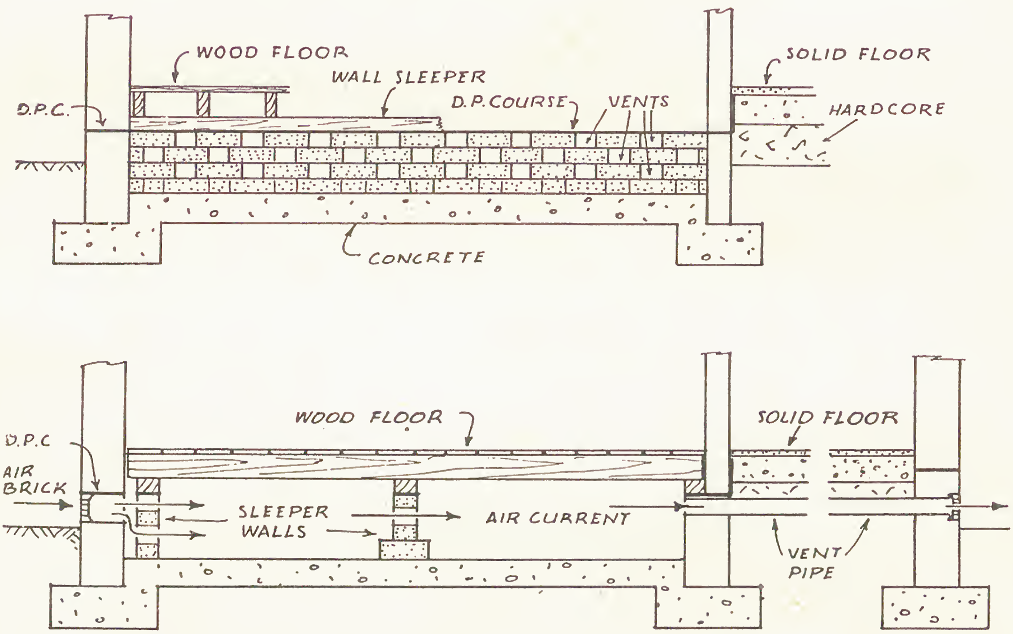


Fig. 49.—Honeycomb sleeper walls and ventilation of wood floors. Top drawing shows sleeper wall in elevation. Bottom drawing shows section through sleeper walls and vent pipe under solid floor.

Mortar Specifications.—A contractor may find that he is required by the specification to supply the architect with the names of the firms from whom the lime was obtained, or that clause may read that the contractor must satisfy the architect by analysis or otherwise that the lime is not adulterated or slaked.

It is also generally demanded that if a mortar mill is not used the material shall be thoroughly screened before mixing and all refractory lumps removed.

Mortar must also be placed on a proper platform when mixed, none being deposited on the ground, and only a sufficient quantity mixed for each day's use.

Mortars are described in Vol. I, Chapter 13.

POINTING

The mortar joints in brickwork may be finished in a variety of ways. The joints may be *Struck* as the work proceeds, which means that the mortar is just cut off flush with the brickwork by means of the trowel, the result being a rough mortar joint with an irregular outline. This finish is growing in popularity.

The Weather-struck Joint is also performed by the laying trowel, the edge of which is used to press the top edge of the mortared joint towards the interior of the wall, leaving a weathering of brickwork over it. The lower edge of the mortar is left rough, as in the plain-struck joint.

Where pointing is done from above, as the work proceeds, especially where the scaffolding is inside the building, a struck joint is sometimes formed with the lower edge of the mortar pressed in instead of the upper edge. This is quite wrong, as it forms a joint which collects the rain-water

The other types of pointing which follow are executed by means of the pointing trowel, used in some cases in conjunction with the cutting rule and a Frenchman.

These consist of the *Keyed Joint, Tuck Pointing*, and *Bastard Tuck Pointing.*

The Keyed Joint is not very commonly met with, and is formed by pressing a rounded tool into the space of the joint.

A similar joint to the keyed joint, in which the depression is square, is used when the brickwork is required to be covered with stucco or rough plaster.

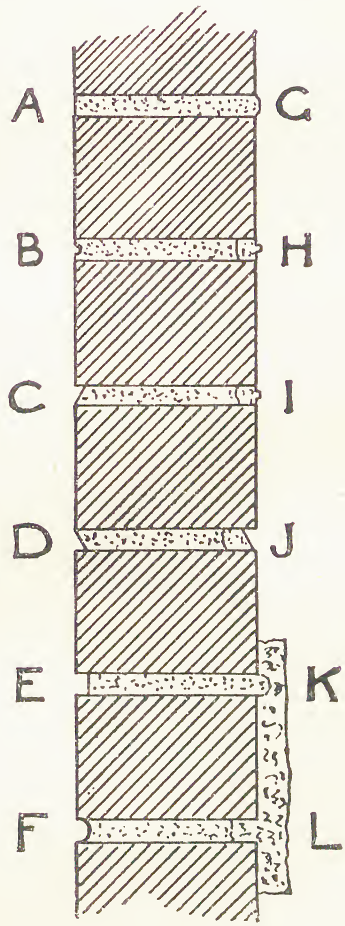


Fig. 50.—Pointing.

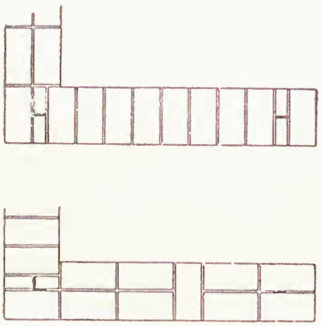
A shows flush-joint pointing.
B ,, V-grooved pointing.
C ,, weathered joint.
D ,, reverse or struck joint
E ,, recessed joint.
F ,, keyed joint.
G ,, projecting joint.
H, I ,, tuck pointing.
J ,, broad pointing
K, L ,, methods of jointing stucco.

Tuck Pointing consists of cutting a narrow channel $\frac{3}{16}$ inch wide in the mortar joint, and filling in generally with mortar of another colour. The filling in may be composed of white lime putty, and left to project beyond the surface of the mortar joint. This form is rarely used nowadays.

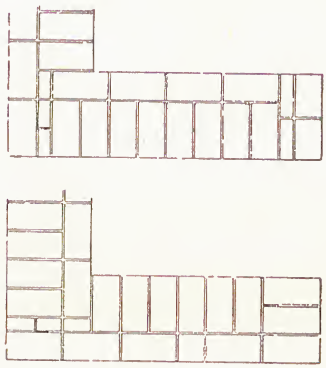
Bastard Tuck Pointing is formed by giving a projecting band to the face of the mortar itself. The vertical joints of the pointing may be pressed into a V section with the point of the trowel.

FORMING CORNERS AND ANGLES

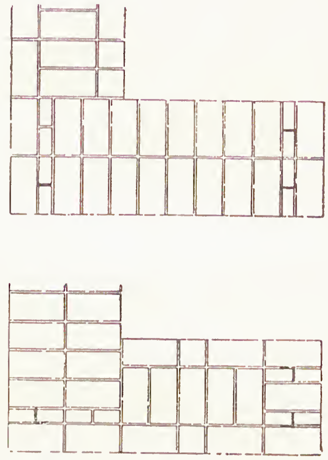
The angles formed by two walls coming together are termed *Quoins*, and as was pointed out above, certain forms of parts of a brick are



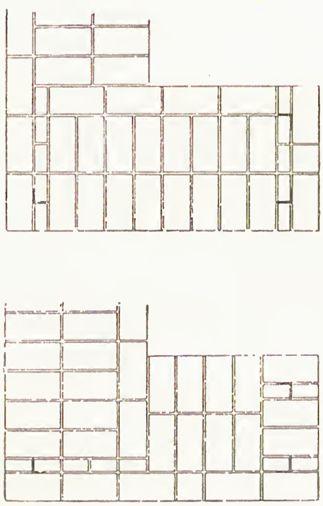
9" WALL.
Fig. 51.



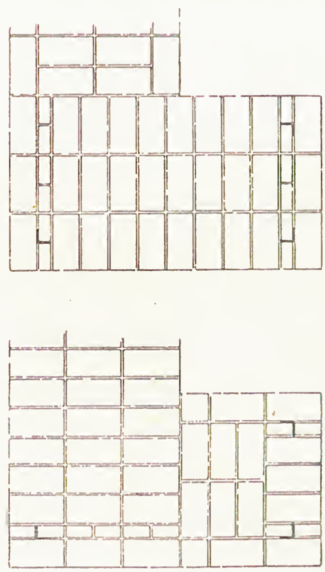
13½" WALL.
Fig. 52.



18" WALL.
Fig. 53.



22½" WALL.
Fig. 54.



27" WALL.
Fig. 55.

Corners and stop ends in English bond.

required to be inserted in order to keep the bond and the perpends of the main walling in their correct position.

The queen closer is generally used for this purpose, being nominally 2¼ inches wide, which is the amount of space that has to be filled up in order to maintain the necessary lap. This closer is placed next to the header at the corner which is called the quoin header. A closer for use with standard bricks should be 2 inches wide.

This matter will be more easily understood if an ordinary 9-inch brick wall built in English bond be considered. If the courses of such a wall are laid without any closers the end of the wall will have every alternative course, that is the stretcher course, projecting beyond the header course.

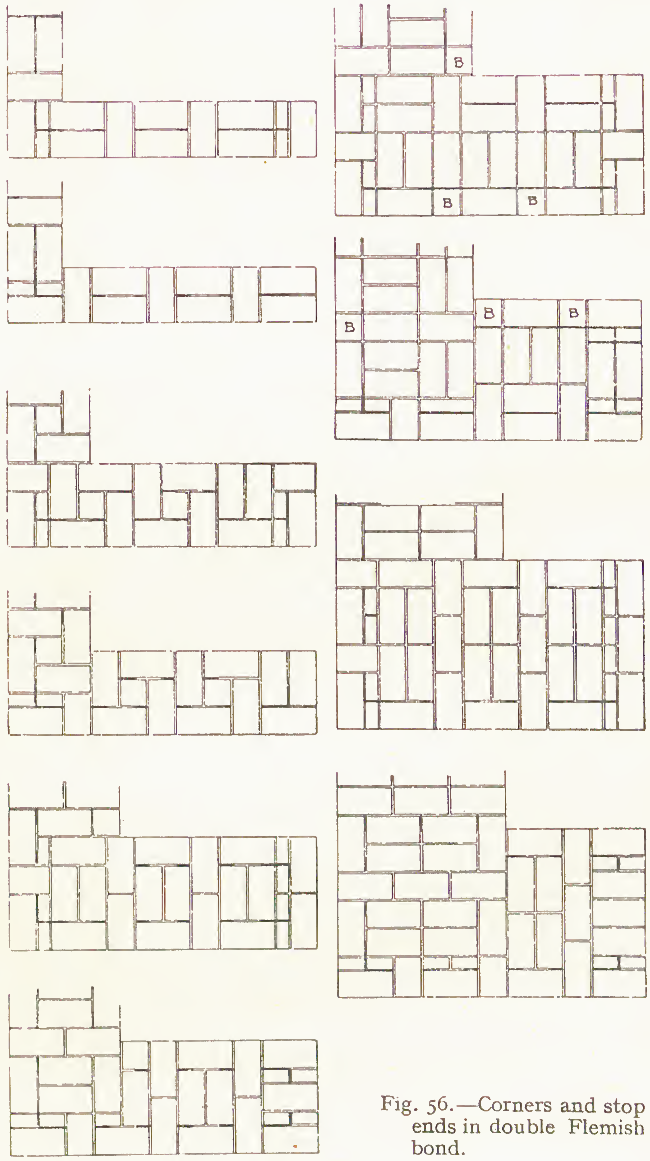


Fig. 56.—Corners and stop ends in double Flemish bond.

The name given to this termination of a wall is *Toothing*, but a wall is only left in this condition when it is required to build on further brickwork at some later date. The end of the wall must be made perpendicular, and in order to do this, when a course of all stretchers has been laid, a header is laid across these, its corners forming a perpendicular line with the corners of the brick below, and next to this is laid a queen closer. The course is then proceeded with in headers.

Corners of Walls in English Bond. — The *Quoin to a One-and-a-half Brick Wall* is formed by laying the stretcher courses as before, only there will now be three instead of two side by side, and the quoin brick above is formed of a three-quarter brick next to which the closer is placed.

The other angle in the same course is formed in the same way, and the course is then proceeded with in the usual manner.

In a *Two-brick Wall* the quoin bricks are full-length ones, next to which the queen closers are placed in one course, but in the course above, that is the stretcher course on the face, the thickness of the wall will require

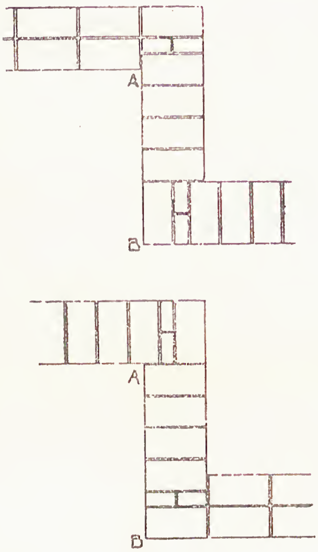


Fig. 57.—Return walls and Z junctions

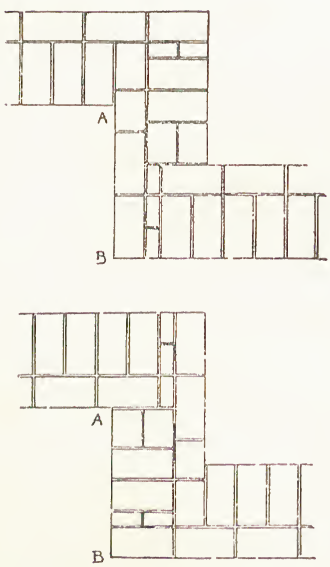
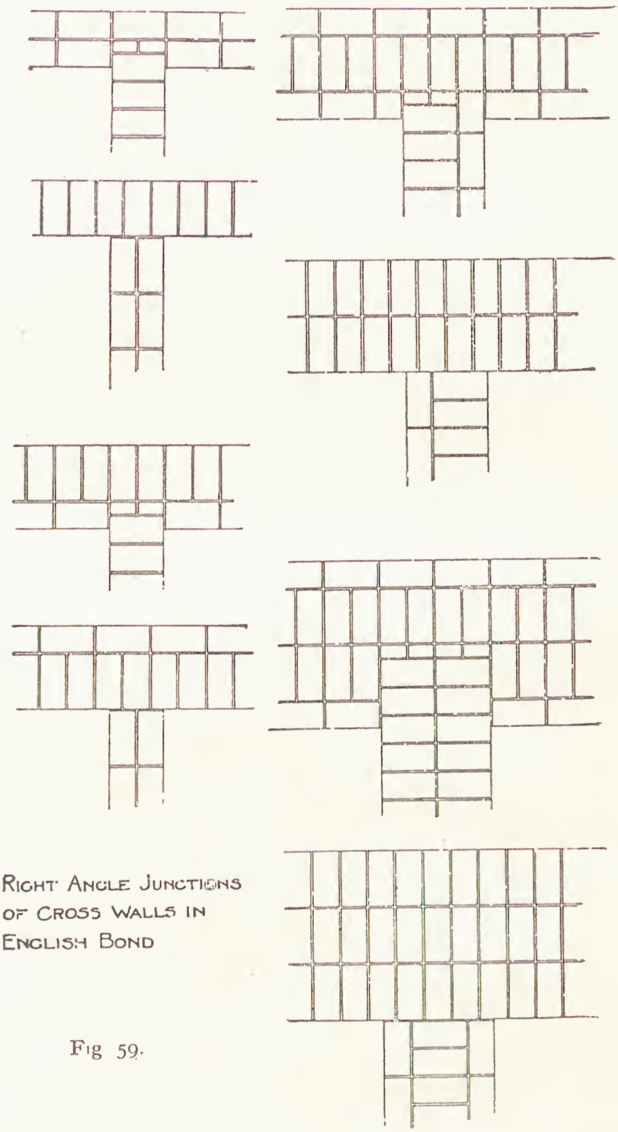


Fig. 58.—Return walls and Z junctions.



RIGHT ANGLE JUNCTIONS OF CROSS WALLS IN ENGLISH BOND

Fig 59.

two queen closers showing at the end of the wall in between the three header faces.

In the *Two-and-a-half Brick Wall* the face has in the stretcher course the queen closer next to it in the same manner as in the 9-inch wall, but the end of the wall will show next to this same brick a three-quarter closer, forming a central header.

The *Three-brick Wall*, having as a basis a course of three headers in line, will have next to them three queen closers. The course above being on the face, all stretchers, and on the return face all headers, will require two $2\frac{1}{4}$-inch closers next to the quoin bricks.

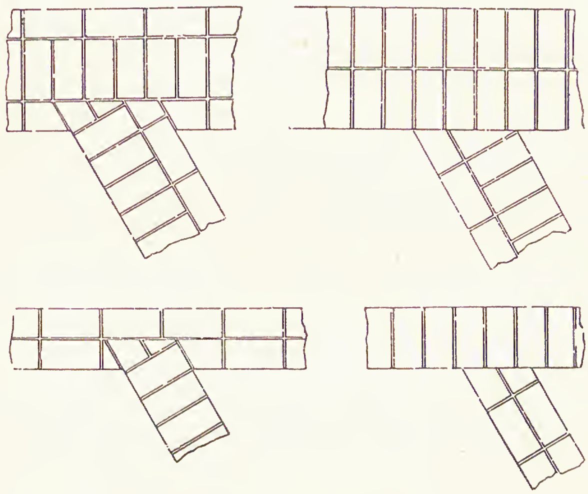


Fig. 60.—Oblique junctions

Corners of Walls in Double Flemish Bond are formed as follows: a 9-inch wall has the closer placed next the header, showing on the face.

The *One-and-a-half Brick Wall* has a three-quarter stretcher bat as a quoin brick, and at right angles to this the stretcher across the wall forming the end has a queen closer next to it. The course above has no closer.

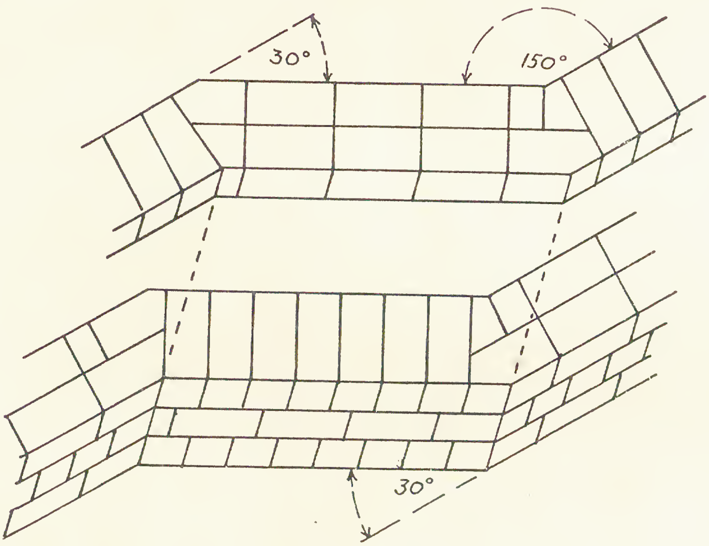


Fig. 61.—Squint quoins, English bond.

The *Two-brick Wall* is formed in the same way as the one-brick wall, a closer being placed next to the header angle quoin, which consists of a three-quarter brick. The other angle of the end is formed in the same manner, and the space between them is filled in with a three-quarter brick.

Corners of Walls in Single Flemish Bond.—The stop end to a wall in single Flemish bond is formed in the following way:

In the *Brick-and-a-half Wall* the same method is employed as in double Flemish bond.

The *Two-brick Wall* is formed without a closer on the face, but the course in which the quoin shows a header at the end of the wall requires a three-quarter stretcher.

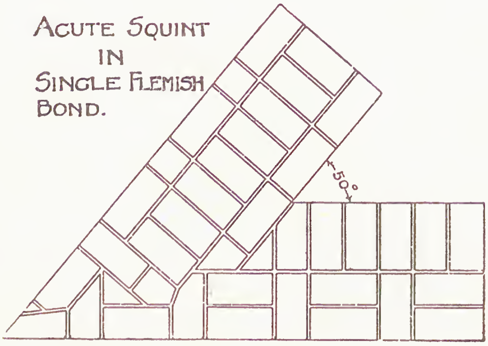


Fig. 62.

The *Two-and-a-half Brick Wall* is formed in the same way, but a half bat is inserted next to the closer, and between it and the three-quarter bat composing the quoin.

Formation of Right-angle and Junction Walls.—The formation of corners at right angles and the junctions of cross walls of a building are constructed in the different bonds, as shown for the English bond in Figs. 59 and 60.

Angles other than right angles are known as *Squint Quoins*, the formation of which may also be gathered from Figs. 61, 62, and 63.

The formation of stop ends as well as return angles are shown in Figs. 51 to 56.

OPENINGS IN WALLS

The openings for doors and windows in brick walls may be either square or rebated.

A rebated jamb is one in which the outer course of brickwork projects beyond the inner course, or courses, thus forming a recess into which the frame is fitted. The face of the projecting outer course is called the *Outer Reveal*, and the face of the recess courses is called the *Inner Reveal*. The bottom of the opening is formed either of stone or brick on edge, and in the case of a window it is known as the *Sill* and in the case of a doorway it is called the *Threshold*.

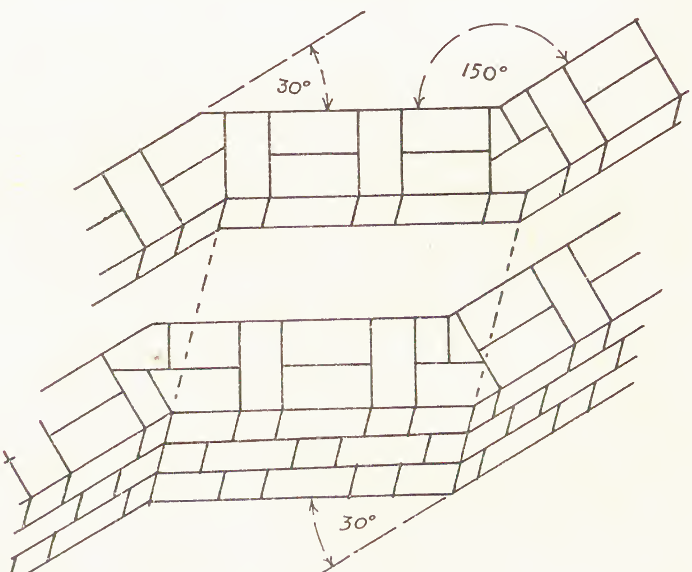


Fig. 63.—Squint quoins. Flemish bond.

The top of the opening is bridged over either by a beam known as a *Lintel*, which may be in wood or concrete, or a brick arch is turned.

As with windows, the bond on the outer face must be kept the same below the opening as above; the dimensions of the opening should be a multiple of the length of a brick. With openings for doors the face brickwork above only has to be considered, but the same point with regard to width of opening should be observed.

Some of the methods of forming the alternate courses for these openings in the various bonds are shown in Figs. 64 and 65.

Rebated jambs in hollow walls must be built so that the inner leaf brickwork is protected from moisture.

Where a sill is formed of stone, the brickwork immediately under it must be prepared at the time the walls are erected, the stone sill being built in later, and is backed up by a course of headers in brickwork. The ends of the stone sill should be formed square, and of a height to fit in the courses, and should project at least $4\frac{1}{2}$ inches into the wall. The sill should be weathered on its upper surface, and project at least $2\frac{1}{2}$ inches from the face of the brickwork, the under surface being throated to prevent water collected on the weathered surface of the sill from running down the face of the brickwork below.

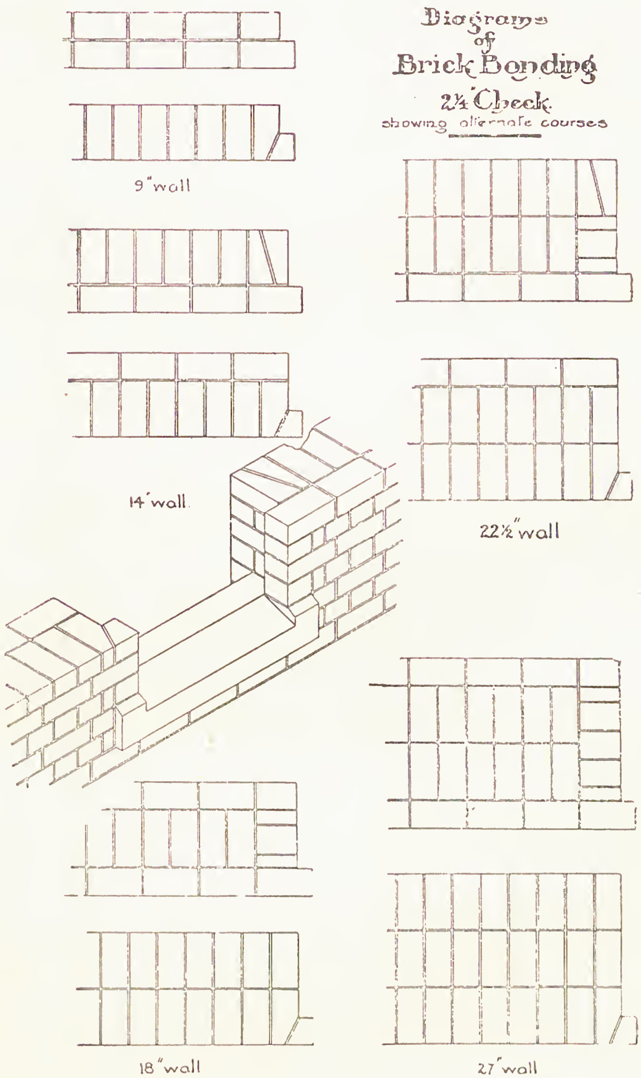


Fig. 64.

Sills are also formed of bricks on edge, which may be either square, bull-nosed, or moulded, in which case the 6 inches in height of two courses of brickwork will require to be made good by the insertion of two courses of tiles, which should be set in cement underneath the brick-on-edge sill.

Sills are also constructed of plain tiles set on a benching of cement, sloping outwards at an angle.

A recent development in office buildings, warehouses, etc., mainly occasioned by the increased vibration in their neighbourhood, is the formation of sills of iron. These are cast either in the form of triangles or bull-nosed. They are cast hollow, 6 inches to 12 inches deep and 9 inches to 12 inches on the base.

Internal Sills.—Where the internal sills of windows are formed by window boards, the brickwork requires no particular finish, except that certain fixing blocks in breeze or concrete may be required to be built in to give a satisfactory holding for the nails.

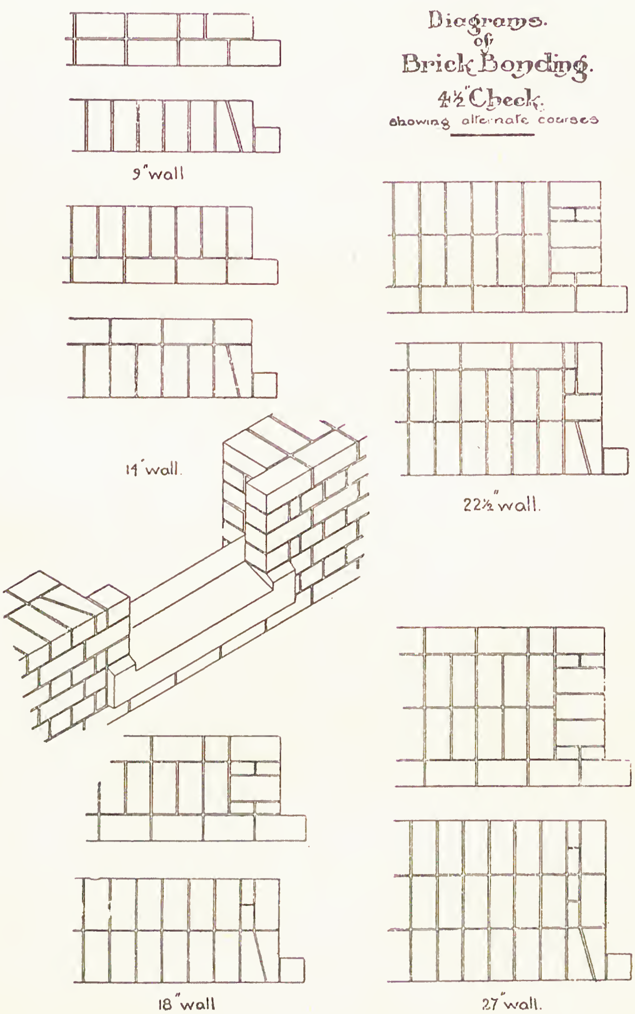


Fig. 65.

Brick Sills.—In office buildings, warehouses, etc., and to some extent in certain classes of domestic work, the internal sills are formed of bricks on edge, which may be either square, chamfered, or bull-nosed.

Tiled Sills.—Nine by nine-inch quarry tiles and ordinary glazed tiles of lesser dimensions are used to form window sills internally, when they should be set in cement, the joint between the wood sill and the tile sill being covered with a cavetto or other mould.

Door Thresholds.—The bottom to an opening to an external doorway is termed the threshold, and is usually constructed of stone. It may, however, in certain styles be formed of bricks on edge, or concrete faced with some durable covering such as Duromit.

The stone threshold should be 6 inches in height, built into the brickwork at its end for a distance of at least $2\frac{1}{2}$ inches and the upper face should be slightly weathered to throw the water away from the door, and the outer face should project about 2 inches from the face of the brickwork underneath.

Brick-on-edge Steps must be set in cement, and packed on tiles in the same way as window sills. The width of a threshold from front to back

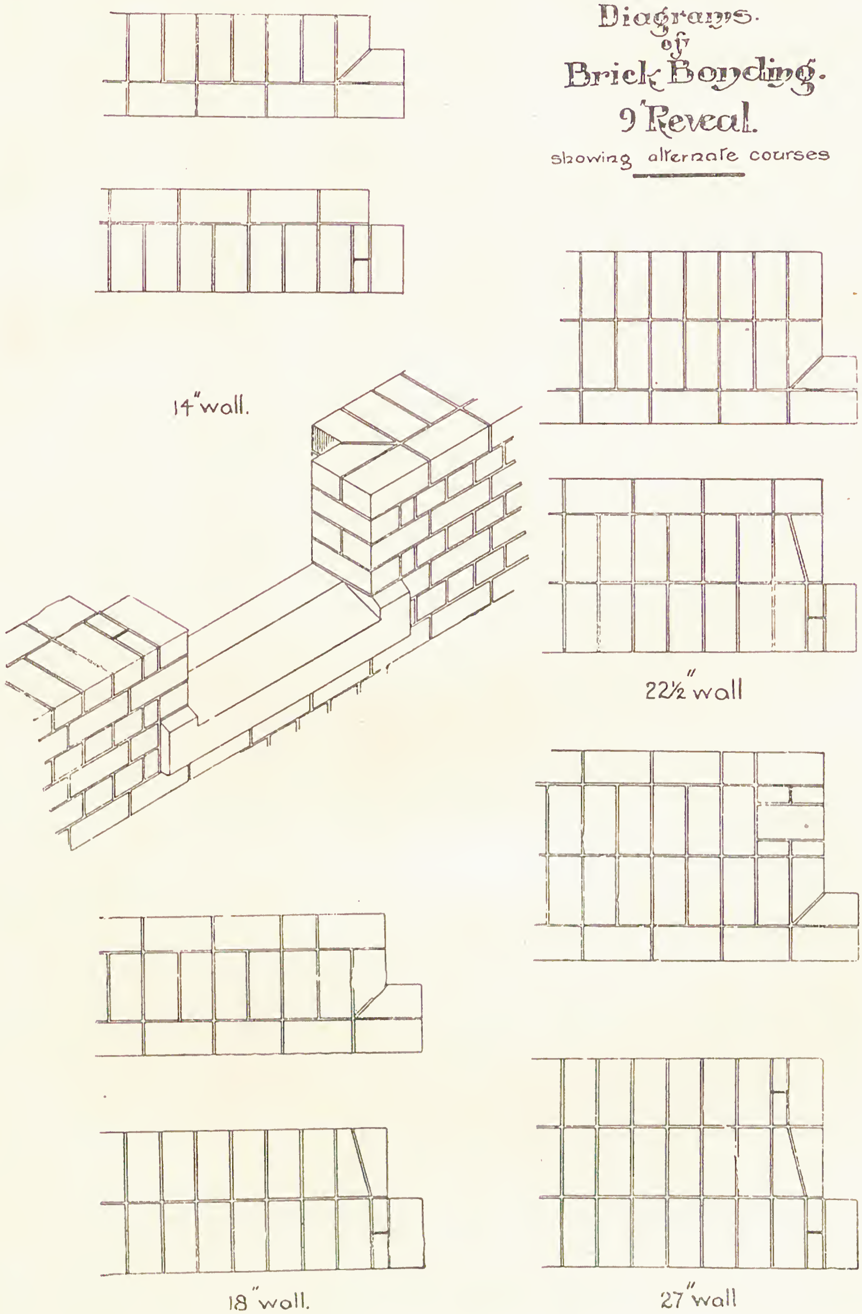


Fig. 66.

should not be less than 12 inches. Therefore, brick-on-edge thresholds will require a backing of stretchers on edge to make up this extra width.

Concrete Thresholds may either be purchased ready made and fitted in exactly the same manner as stone thresholds, or they may be cast on the job and, if necessary, reinforced with steel rods.

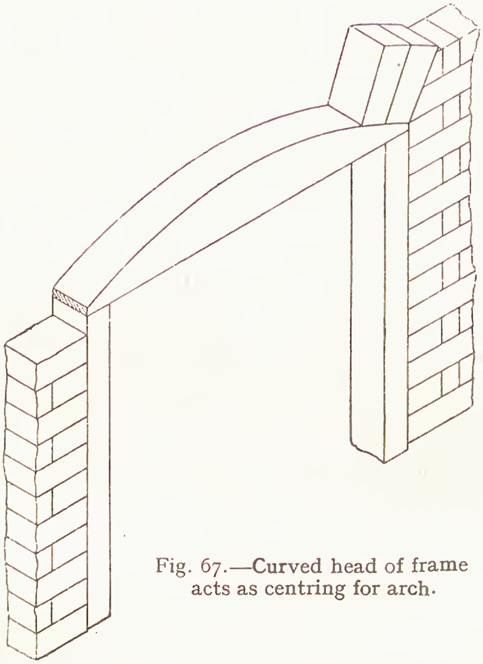


Fig. 67.—Curved head of frame acts as centring for arch.

Carrying Openings.—The brickwork over openings may be supported either by a flat beam, when it is termed a *Lintel,* or by some form of arch constructed of brickwork. Or there may be a combination of both lintel and arch.

The Lintel may be of wood, stone, concrete, or steel.

Another name for the actual beam itself is a *Bressummer.*

The actual size of a beam required must be worked out mathematically in order to obtain the requisite strength to support the load which has to be carried.

All forms of the beam must be bedded on an exact level in the wall, and where a steel beam is used the ends in the wall should rest on a stone template, so that the weight may be spread over the entire thickness of the wall, and there should be a lead pad plate placed between the stone template and the beam.

For walls of $4\frac{1}{2}$ inches thickness the ends of the beam should be built in at least $4\frac{1}{2}$ inches, but where greater weights have to be carried, and reinforced concrete or steel beams are used, they should have a bearing on the wall of 9 inches. To distribute the weight carried by the beam to enable a smaller beam to be used, arches are turned in the brickwork, over the beam, the space underneath being filled in with brickwork. Arches serving this purpose are termed *Relieving Arches.*

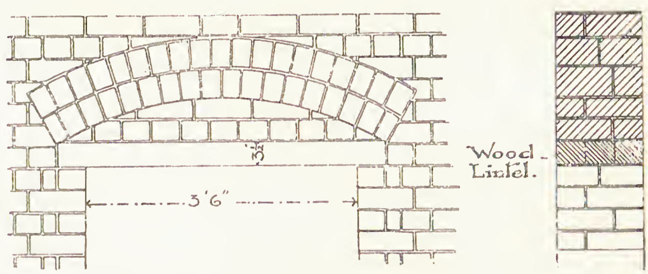


Fig. 68.—Flat wood lintel with relieving arch over.

Arches are also formed of plain roofing tiles, when the cement in which they are set forms the wedge necessary to the support of an arch.

The Principle of an Arch.—The principle underlying the construction of an arch is the transference of a direct downward pressure occasioned by the weight of the brickwork over an opening to the jambs at the side of that opening. This is effected by the building in of wedge-shaped blocks, each of which, by pressure on the one next to it, redirects the downward pressure to the side of the arch known as the *Abutment.* The wedged-shaped blocks of an arch are known as *Voussoirs*, the central voussoir at the top being the keystone, and the bottom voussoir being known as the *Springer.*

Where the springer is placed upon an inclined surface on the abutment, this surface is known as the *Skewback.*

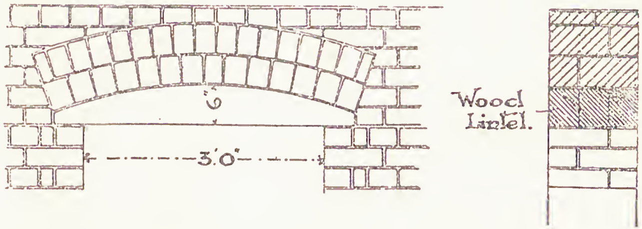


Fig. 69.—Curved wood lintel and relieving arch over.

The under surface of an arch, as seen by anyone looking upwards within the opening, is known as the *Soffit*, or in classical language, the *Intrados.*

The outer surface or outer ring of the arch is known as the *Back*, or *Extrados*, and the lower portion of this back is called the *Haunch*, whilst the top of the back is called the *Crown.*

The width of the opening over which the arch is turned is called the *Span*, and the triangular space formed by a perpendicular line drawn from the outer corner of the lowest voussoir until it meets a horizontal line drawn through the crown is termed the *Spandrel.*

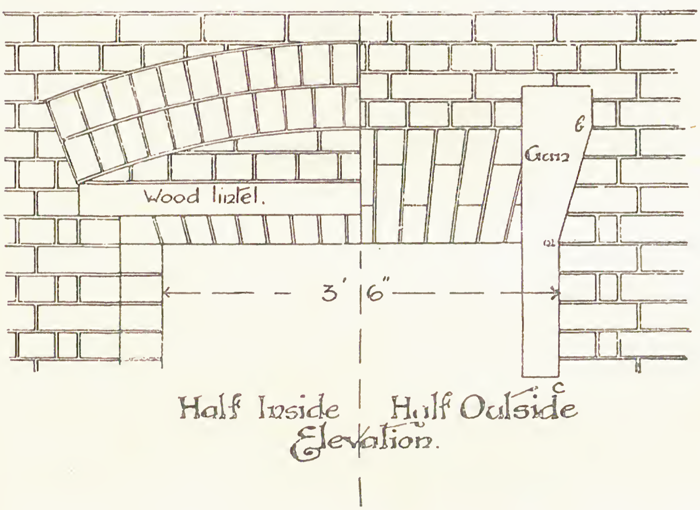


Fig. 70.—Inside and outside treatment of opening.

The *Centre* is the point from which the arch is struck and, as is explained later in Composite Arches, there is more than one of these.

Where two arches come together on a central support of brickwork, that centre is termed a *Pier*, and the vertical face of piers and abutments are known as *Jambs.*

Where the upper portion of a pier has a portion of it of a larger area than the pier below, forming a square block in the nature of a *Capital*, this is termed an *Impost.*

Courses parallel to the arch are known as *Ring Courses*, and those in the immediate neighbourhood of the arch, and at right angles to the face, are termed *String Courses.*

The joints between the blocks forming the ring courses are termed *Heading Joints*, whilst those between the blocks of the spring courses are termed *Coursing Joints*.

The horizontal line drawn across the opening to the arch from skewback to skewback is known as the *Springing Line*, and the distance from the springing line to the underside of the Crown is termed the *Rise* of the arch.

The width of the opening across which the arch is struck, that is, the horizontal space between the abutment, is termed the *Span*, and the

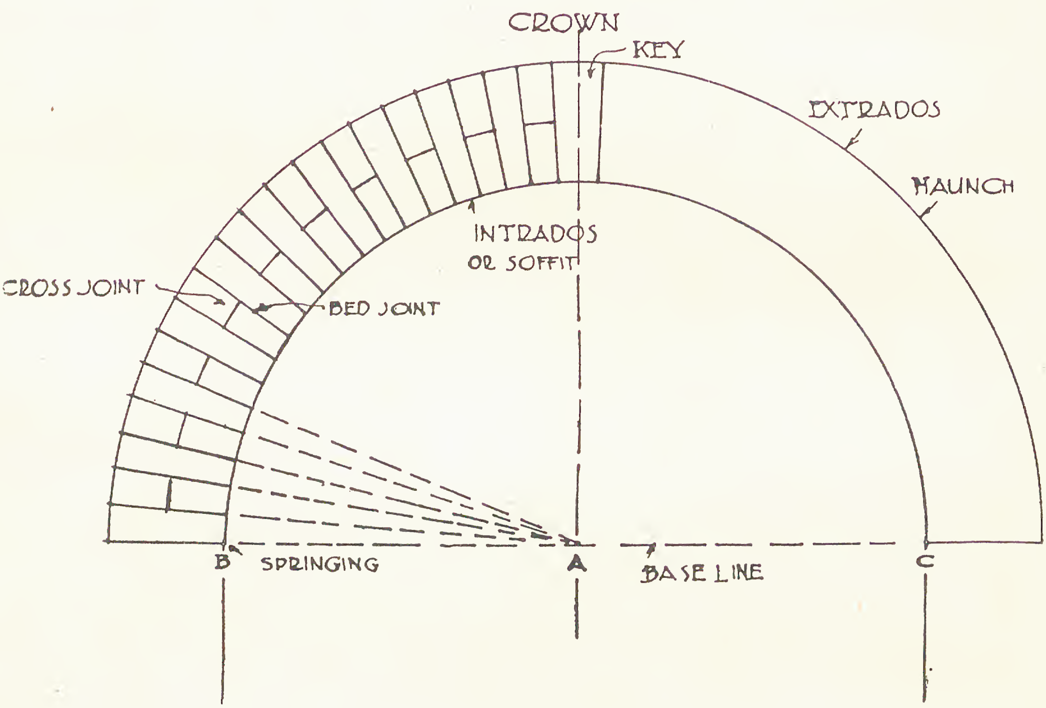


Fig. 71.—Semicircular arch.

dimension between the soffit and the back of the arch is termed the *Depth* or *Thickness* of the arch.

The length of an arch is the horizontal distance between its two faces, or in other words the length of the soffit.

Shapes of Arches.—*Flat Arches.*—So long as the skewbacks are formed at an angle such that if the lines of their surfaces are produced they will meet at a point within the opening, an arch may be constructed having a flat soffit. However, as in actual practice an arch with an absolutely level soffit has a tendency to look as if it sags in the middle, it is always advisable to give a rise of an inch or so.

The joints of a flat arch should all radiate from the centre, found as already explained at the junction of the lines of the skewbacks produced.

And in order to increase the key of these joints in a flat arch, they are sometimes rebated, though this applies more to arches in stone than in brickwork.

Shaped Arches. — Arches, as they are more generally understood, are of a variety of shapes, which may be divided into *Single Arches* which are struck from a single centre, and *Compound Arches* which are struck from more than one centre. The flat arch is the most simple form of single arch, the *Segmental* and *Semicircular* being the other two forms.

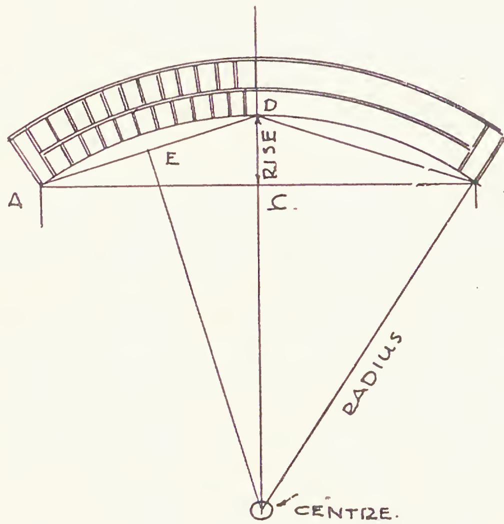


Fig. 72.—Striking a segmental arch.

The centre of a semicircular arch is a point on the springing line equidistant from both jambs.

To find the centre of a segmental arch the required rise must be known. The span is then divided equally, and a vertical line drawn upwards through that point. The rise is then marked on this vertical line.

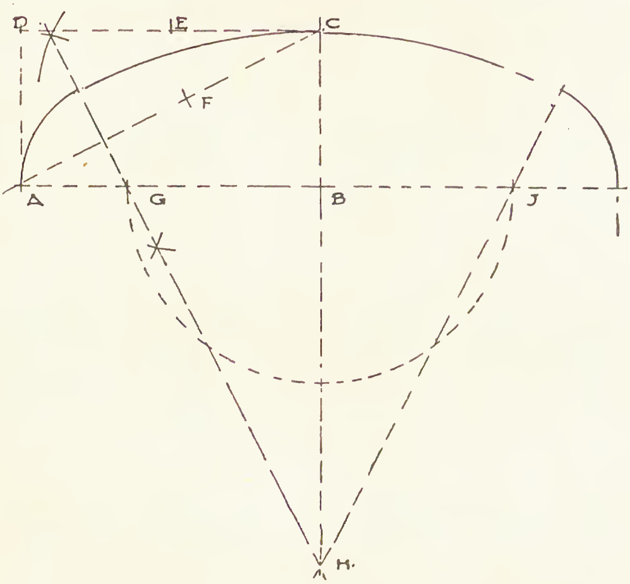


Fig. 73.—Striking a three-centred arch.

If the span is termed AB and the dividing point called C, the rise is CD. Join the points DA and DC ; divide AD into two equal parts at E, and from E draw at right angles to AD a line produced till it meets DC produced, calling the point O at which this line cuts DC produced. This point O will be the centre of the segmental arch.

The radius of an arch is the line drawn from the centre to the springing, and the length of the radius may be found when the length fo the span and rise are known from the following formula :

$$\text{Radius} = \frac{\text{half span}^2}{\text{rise}} + \text{rise} \times \frac{1}{2}.$$

In the semicircular arch the rise is equal to half the span, and in the segmental arch the radius is always larger than the rise.

Compound Arches. — The most usually met with forms of compound arch in building are the *Semi-elliptical* (this is also known as the *Three-centred Arch*), the Tudor or *Four-centred Arch*, and the *Gothic* or *Pointed Arch*, which may be either *Lancet*, *Equilateral*, or *Drop*.

A further type of compound arch is known as the *Rampant Arch*, which is formed of two segmental arches, of different sizes and at different levels. This last, however, is not frequently met with in building construction.

Vaulting.—A vault is a continuous arch used in passages underground, and may be so constructed that two vaults cross one another, in which case one vault is made continuous and the other diminished to die out against it.

The centres for the arches just described are obtained in the following manner:

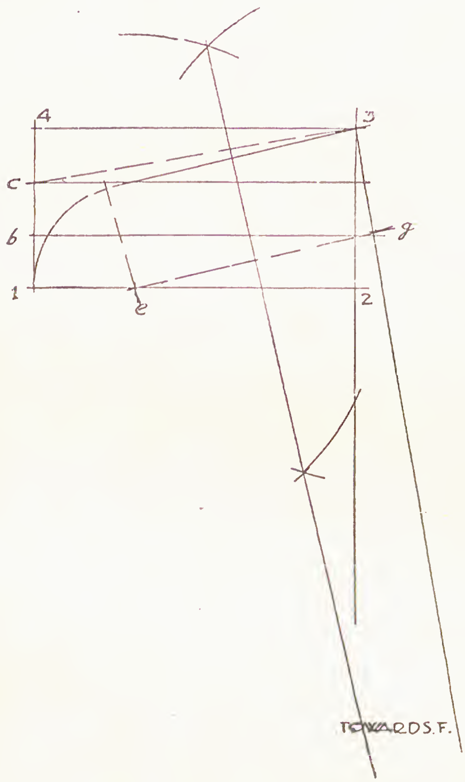


Fig. 74.—The four-centred or Tudor arch.

To find the Centres for a Three-centred Arch draw the rectangle A, B, C, D, and the diagonal AC. Along DC cut off DE equal to DA. Along the diagonal from C cut CF equal to CE. Bisect FA, and where the bisection cuts the springing line at G is the centre for the lower curve, where it cuts the centre line at H is the centre for the upper curve.

The third centre is found by making BJ equal BG (see Fig. 73).

To find the Centres of a Four-centred or Tudor Arch, draw the rectangle 1, 2, 3, 4, and divide this into three equal rectangles. Mark off a distance along 1, 2 equal to 1*c* which gives the centre of the lower curve at *e*. Join C3. Draw the line 3*f* at right angles to C3, and make 3*g* equal to 1*c*. Join *eg*, and bisect, and where the bisector cuts the line 3*f* will be the centre of the second arch (see Fig. 74).

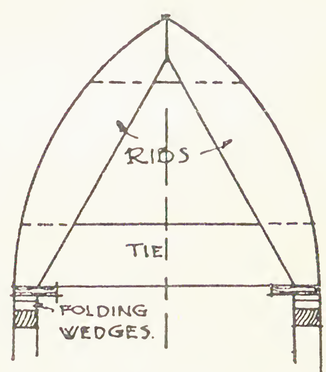


Fig. 75.—The Gothic arch.

In a Gothic or Pointed Arch, where the rise is too steep to allow of the centre being cut conveniently out of one board, the ribs are built up out of two or more sections, 1 inch to 2 inches thick by 7 inches to 11 inches wide, well secured with nails driven through and turned over at breaking joint.

A further classification of arches is one descriptive of the methods employed in their construction, as follows:

Rough Arches.—In a rough arch the bricks are used of the sizes as

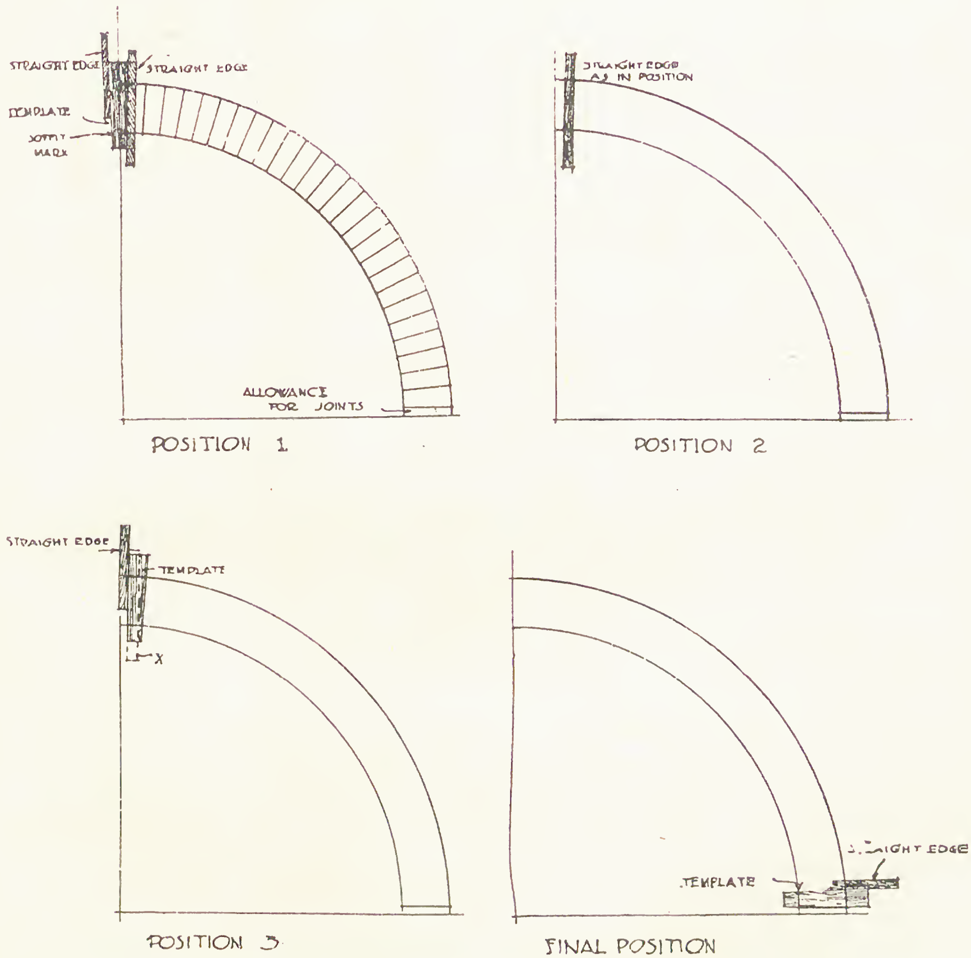


Fig. 76.—Setting out semicircular arch in gauged brickwork

made, without being cut in any way, and in these it is the mortar used in the joint being wider at its outer edge than at its inner which forms the necessary wedge.

These arches may be built in one or more rings.

The relieving arches already referred to formed over the lintel to an opening are usually built in rough arches. They are generally segmental in form, and built of two or three rings of uncut bricks on edge. The space underneath is filled in with brickwork shaped to fit the underside or soffit of the arch, and is termed the *Core*.

Axed Arches are those in which the bricks are cut roughly to the shape of a template made in the required wedge shape. In cutting the scutch and blade are used, and when roughly cut in this manner the bricks are rubbed on a stone to take off any projections.

The jointing is done in neat cement of from $\frac{1}{16}$-inch to $\frac{1}{8}$-inch in thickness, the joint itself having parallel sides and not wedge-shaped, as last described.

To afford an extra key to the joint a groove may be cut in the side of each brick, into which the cement is poured from above after all the arch bricks have been placed in position.

Gauged Arches.—These are formed of specially made bricks which are of a soft nature capable of being easily cut and rubbed to the required dimensions. They are known as rubbers. The manner of cutting employed is as follows. The bricks are cut in a box slightly larger than the required size, and they are then rubbed down to the exact size of a template of tin, cut from a full-size drawing made of the whole arch cut from the required centre. The jointing is performed by dipping into fine lime putty, the finished joint when the bricks are in position being not more than $\frac{1}{16}$ inch in width and parallel. (See Fig. 76.)

Lacing Courses.—Where a rough arch is required to consist of several rings, in order to afford it extra strength, certain long bricks are introduced stretching from the face to the back of the arch. These are termed *Lacing Courses*, and whereas in the rough arch the sides of the bricks do not radiate actually from the centre itself, but from a small circle struck round the centre, the lacing courses do actually radiate from the centre.

The *Checked Skewback.*—Rough arches are sometimes sprung, not from a flat surface, but from a skewback, the surface of which is checked. The first arch brick starts from the springing line to form the lower arch, and those of the arches above are set back 1 inch each, the bricks in the courses of the walling having been cut to receive them.

The *Dutch Arch.*—This is a form of flat arch which is not recommended for ordinary building work on account of its weakness.

The bricks are uncut, and the jointing is parallel to the skewback. A point is reached in the construction when the bricks meet at a point at the centre of the arch, leaving an unfilled portion having the shape of a V. This V is filled in with further bricks parallel to the others, but terminating against the sides of those already in position.

The *Bastard or Key Arch.*—This form is not really an arch in the proper meaning of the word. It consists of two flat arches meeting at the crown, leaving as before a V-shaped opening. This opening is filled in with a key brick.

The *Inverted Arch* is used between piers in foundations, especially where the subsoil is of a compressible nature. It serves, not only to distribute the weight over the foundation, but also to steady the piers against side thrusts. Its formation is similar to that of the ordinary rough relieving arch. The width of the opening between the piers is measured, the centre line is drawn, and a point 6 inches up from the base line at the centre is marked. A strong abutment is essential to an inverted arch, especially for the outer arches of a series.

CORBELLING AND OFFSETTING

Offset courses in a wall are the surfaces afforded by setting back the upper wall to a less thickness than the wall below, as for example when a foundation wall 1 foot $1\frac{1}{2}$ inches is set back on one face and continued as a 9-inch wall. A horizontal surface of $4\frac{1}{2}$ inches is left inside, and this is termed the offset.

Where the offset is only $2\frac{1}{4}$ inches, this is not sufficient for the purpose generally required of it, namely, to support a wall plate on which the joists rest. The two courses immediately beneath the wall plate are built out, each projecting $1\frac{1}{4}$ inches, thus forming a level surface on which to rest the plate of $4\frac{1}{2}$ inches. These two projecting courses are termed corbel courses.

A corbel, as distinct from a corbel course, is an isolated projection for the support of some isolated member, such as a tie beam to a roof. This is generally formed of three short courses projecting each $1\frac{1}{4}$ inches, frequently capped by a York-stone template, to distribute the pressure more evenly over the brickwork.

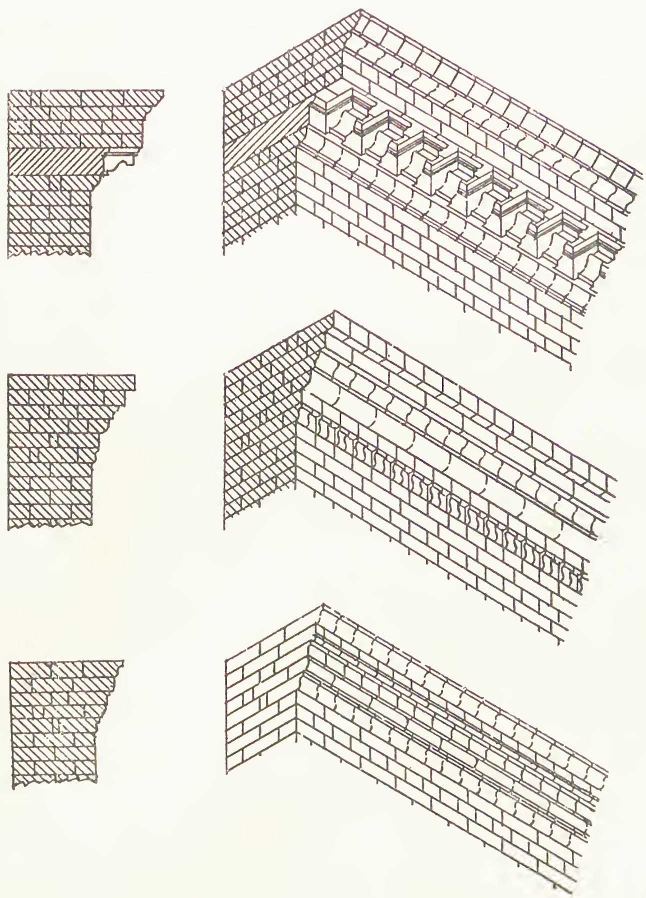


Fig. 77.—Corbelled cornices.

Corbel courses are also used externally as a finish to roughcasting, when they are also termed string courses, and to afford additional support to eaves-gutters when they are built of moulded and decorated brickwork.

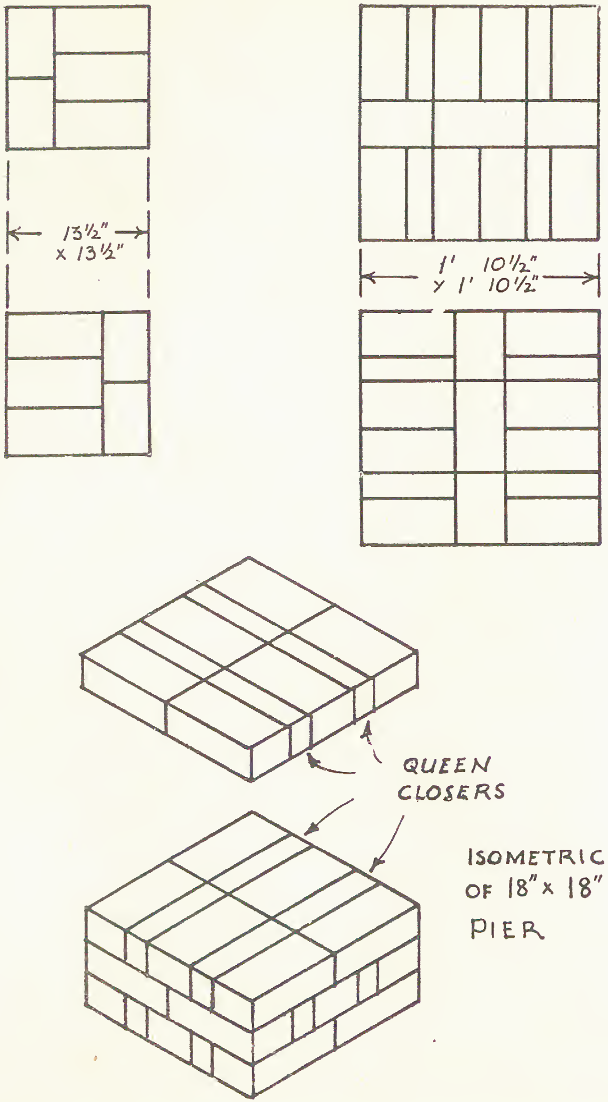


Fig. 78.—Piers in English bond.

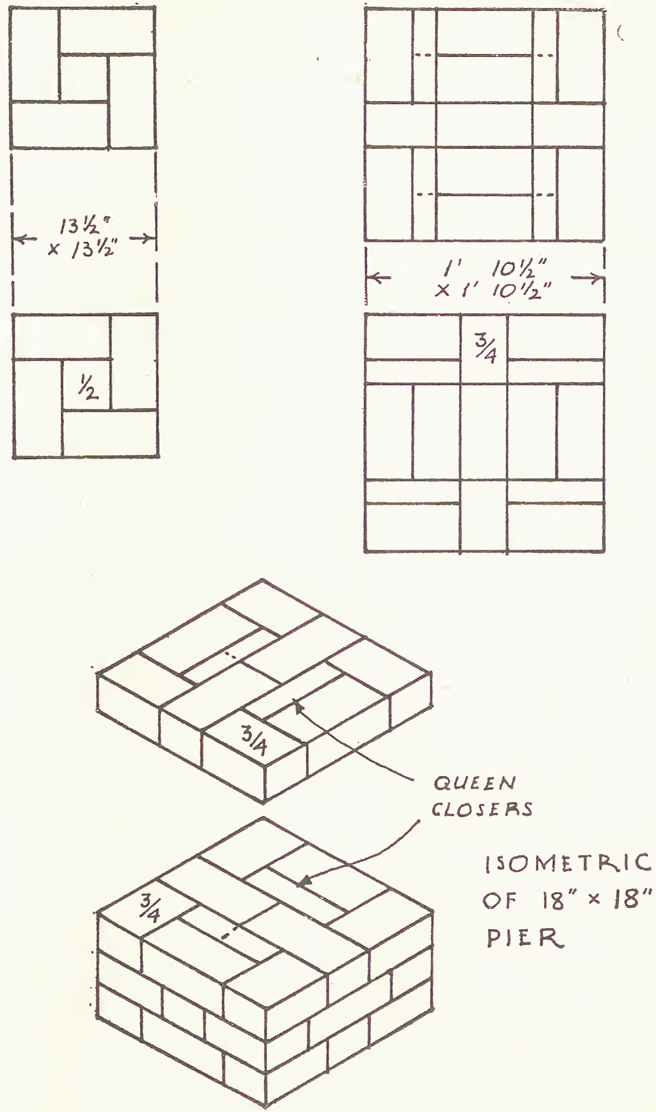


Fig. 79.—Piers in Flemish bond.

Their proper bonding into the main wall is an important consideration, and should consequently be constructed mainly of heading courses.

A decorative corbel eaves course may be designed as a cornice, having stone brackets supporting the main projection of the cornice. These brackets should be built as far as possible into the wall.

An alternative to corbel courses for the support of wall plates are *Wrought-iron Pins*, known as *Corbel Pins or Brackets*, which are built into the brickwork at least 9 inches, at which point their ends are turned downwards into the brick joint, and left to project $4\frac{1}{2}$ inches from the face of the wall, the projecting end being turned upwards.

PIERS

A pier as distinct from a column is some form of square, rectangular, or octagonal pillar used to support loads in a building, for transmission

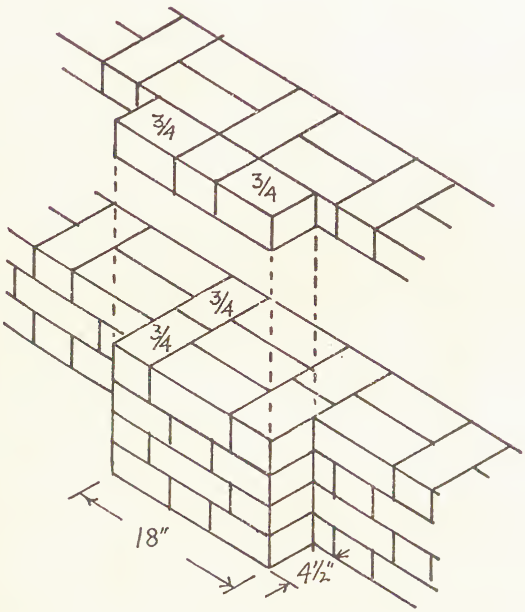


Fig. 80.—Attached pier $18\frac{1}{2}$ inches by $4\frac{1}{2}$ inches, Flemish bond.

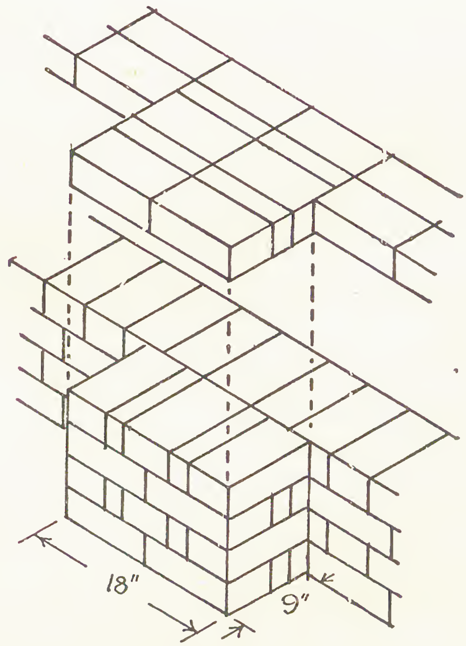


Fig. 81.—Attached pier 18 inches by 9 inches, English bond.

to properly constructed foundations, whereas a column applies to pillars which are circular on plan, though used for the same purpose.

Piers and columns are constructed of brickwork, timber, concrete, and steel.

Brick piers which are required to carry very heavy loads are cored with steel stanchions.

The angles of bay windows are also built up as piers in between the sash, when they are known as *Squint Piers*.

Square Piers in Brickwork in English Bond are built in the manner shown in Fig. 78, which shows the alternate courses in piers of varying thicknesses. The 9-inch square pier is formed of courses of headers alternately.

The *One-and-a-half-brick Pier in English Bond* shows a stretcher and a header in alternate courses on one face, and alternate courses on the other face, composed of three half bricks to one course and two three-quarter bricks on the course above.

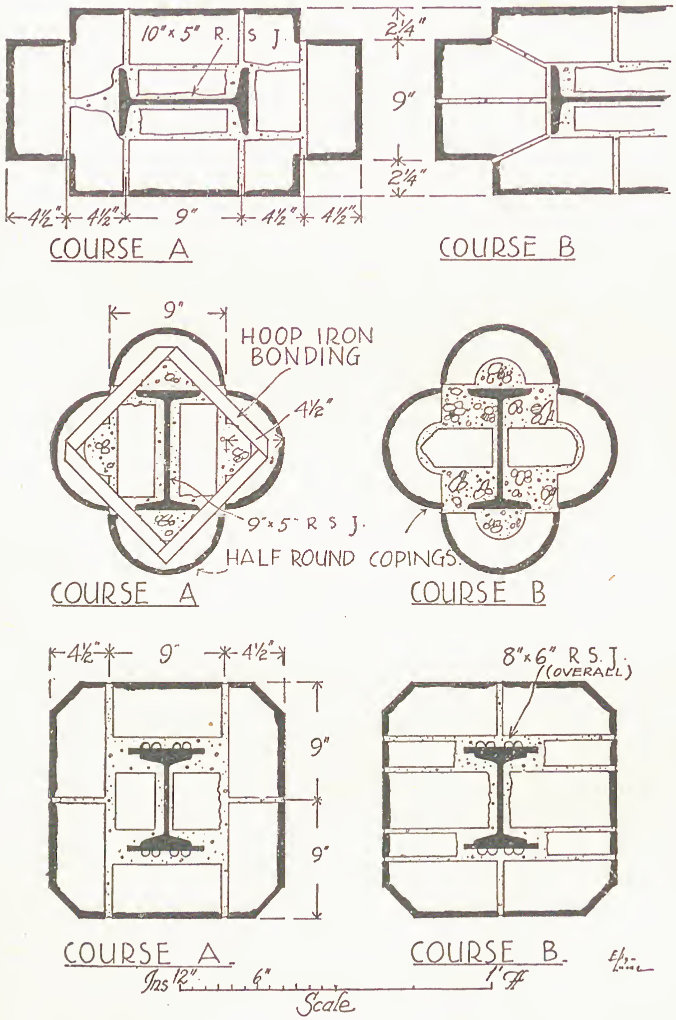


Fig. 82.—Brick casing to R. S. stanchions.

The *Two-brick Pier in English Bond* shows two stretchers with three headers above, having stretchers between.

The *Two-and-a-half-brick Pier in English Bond* shows one course composed of two stretchers with a header between and a course over, composed of a header at each end, two headers in the centre of the pier, the intervening spaces being filled in with closers.

Square Piers in Flemish cannot be built to 9 inches.

The *One-and-a-half-brick Pier in Flemish Bond* shows a header and a stretcher in alternate courses on all four faces. This bond is particularly suitable for piers which are cored with steel columns, as it leaves a space in the interior, having a straight line from top to bottom. Where there is no steel column this space is filled in with a bat.

The *Two-brick Pier in Flemish Bond* has alternate courses composed of two three-quarter bricks divided by a header, and two headers divided by a stretcher. This stretcher is built in the form of a bevelled closer.

A *Two-and-a-half-brick Pier in Flemish Bond* shows on the face alternate courses composed of two stretchers divided by a header, and a course above having a header at the angle, a stretcher in between separated at each end by closers.

Typical bondings of *Attached Piers* are shown in Figs. 80 and 81.

In frame buildings the beams supporting the joists of the ground floors are formed of brick piers, generally 9 inches square, and forms of construction in brickwork have been designed for the saving of material which consist of panels keyed into piers.

VENTS

For ventilating the space under wood floors, and the cavity in hollow walls, there should be openings formed in the brickwork which are filled in by 9 × 6-inch gratings. These ventilating gratings are to be obtained either in cast iron or terracotta. Perforated bricks are also used for the same purpose, though it is to be doubted if the amount of air which these last admit is sufficient.

PAVING IN BRICKS

The floors to verandahs and other enclosed spaces are often paved in brickwork. For this any ordinary standard bricks may be used, though it is preferable that they should be of the harder type.

Blue bricks, which are sometimes used, are apt to be slippery, though they of course give the best durability.

Bricks used for paving should be laid on edge, bedded in concrete and jointed in cement.

Where steps are required in brickwork, as for example over an area, a two-ring rough brick arch of the half-rampant design should be struck from below the level of the first step to below the level of the top step. On this should be laid concrete, in which seatings are formed to receive the bricks on edge.

CHAPTER 2

ORNAMENTAL AND GAUGED BRICKWORK

Whereas in the past it was generally felt that brickwork, to have a satisfactory appearance, should present a uniformity of colour, variety is now considered of greater importance. To meet this demand manufacturers now supply bricks of a great variety of colour and texture, not only brick varying from brick, but of a mottled hue and variations of colour in the individual brick.

RUBBERS

Gauged work proper is the class of brickwork requiring the most skill in execution. It is executed in Rubbers, which are made of sandy clay, lending itself to cutting and rubbing to any required shape. A good Rubber should be of the same colour throughout, in order that any portions that are rubbed more than others may not give a variety of colouring to the whole. And the interior of the brick must be as weather resistant as the exterior. The best Rubbers are Fareham Reds and T.L.B. Rubbers for Reds; Malm-Cutters and sometimes White Suffolks for Malm and Stock Brickwork.

It is essential in a Rubber that it should case-harden, and not flake off or wear down on weathering, causing the putty joint to stand out from the surface.

Case-hardening in brickwork is attributed by some to the effect of the weather on the outer surface of the brickwork, whilst others claim that this is due to the soaking to which the bricks are subjected whilst the work is in process.

This water containing more or less lime in solution is taken up by the brick whilst soaking, and upon exposure it becomes carbonised on the outer face and so forms a hard coating.

A third theory as to the cause of case-hardening is that the silicic acid in the clay acts upon the chalk so as to form it into silicate of lime.

Rubbers are box-moulded and baked. The distinction between baking and burning, as for other bricks, is that in baking they are heated sufficiently to rob the material of its plasticity, with the result that they are soft and dead, producing no ring when they are struck together.

Rubbers are made longer and wider than ordinary brick to allow for rubbing and cutting; T.L.B.s, as they come from the yard, being $10\frac{1}{2} \times 4\frac{7}{8} \times 3\frac{1}{8}$ inches. When used for arches, they are 10 inches long.

The crushing strength of Rubbers is only 74 tons per square foot.

Rubbers are set in white putty, the joint being less than $\frac{1}{32}$ inch.

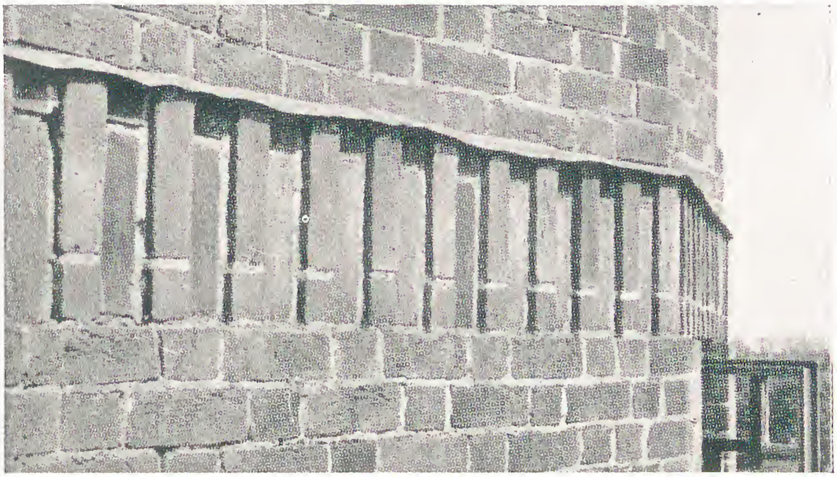


FIG. 83.—ORNAMENTAL BOND WITH BRICKS ON END AND EDGE.

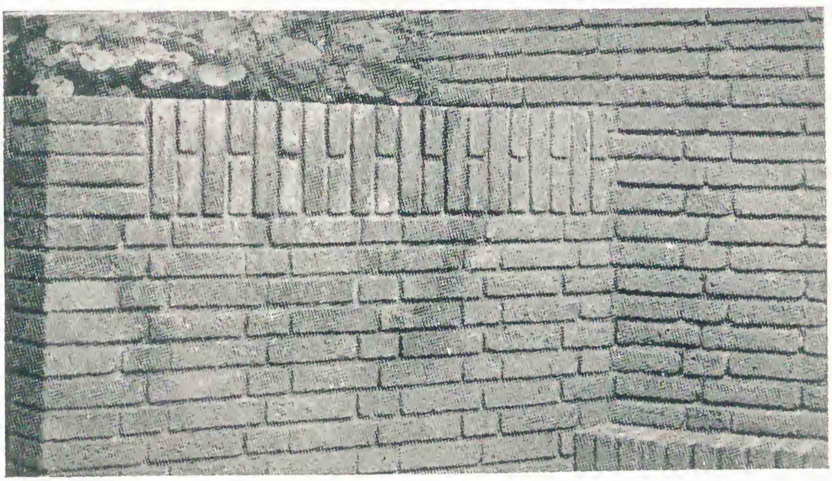


FIG. 84.—A MODERN BOND (ONE HEADER TO TWO STRETCHERS) THREE-QUARTER BRICK AT QUOIN TO AVOID CLOSER.

PANELS OF ORNAMENTAL BRICKWORK GABLE END WITH BARGE BOARDS VERGE WITH TILE UNDERCLOAK AND HOG-BACK RIDGE (Wheatley & Co.).

The method of jointing is to hold the Rubbers down into the putty in a putty box. This box must have a level top to enable the brick to be dipped level, so that the jointing face may be covered equally with putty. To ensure an equal and fine joint, the putty should be scraped off the centre of the bed. Stone lime should be used for outside jointing in making the putty, as chalk lime is unsuitable.

Axed work is generally set with putty and cement.

In brickwork that is to be carved a composition of whitening and patent knotting is used, but it should be noted that the bricks intended to be set in this should be free from moisture. Consequently they should be stacked in a good weather-tight shed.

DIAPER WORK

Decorative patterns are to be obtained in brickwork by using bricks of a different colour in the formation of patterns. Though not so frequently seen in modern work, some very fine diaper patterns are to be seen in

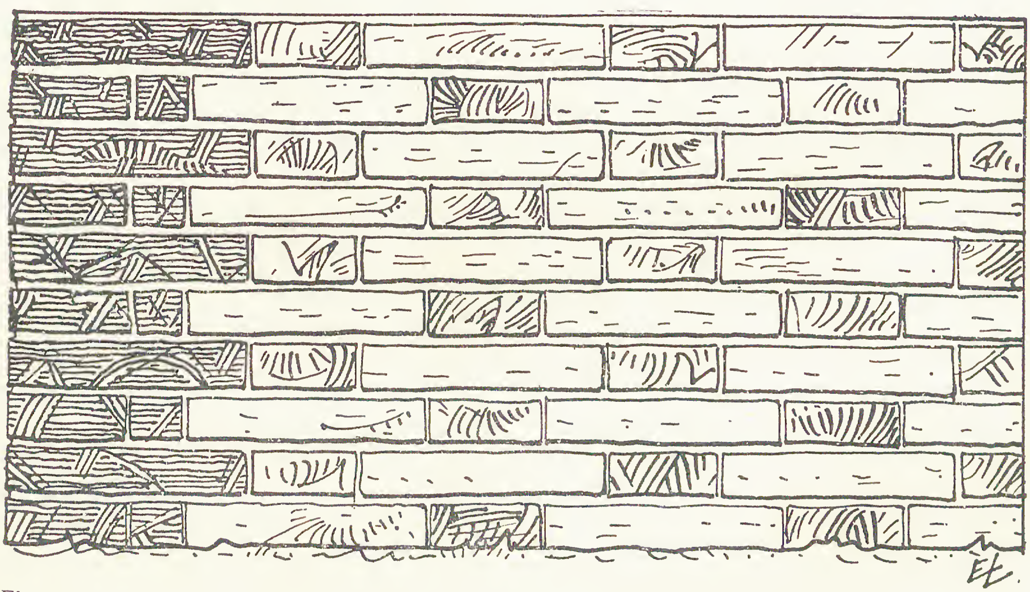


Fig. 85.—Corner bricks of dark colour; walling headers of medium colour; stretchers light colour. This relieves the plain character of large wall areas.

East Anglia, executed by the Flemish weavers who settled there during the fourteenth century.

Quoins at the angles and at the openings of windows and doorways are frequently carried out by the use of bricks of another colour, as also are arches.

SETTING OUT AN ARCH IN GAUGED BRICKWORK

The setting out of an arch in gauged brickwork is performed on a board on which the work is drawn out in chalk to full size. The bricks are then cut and rubbed to these sizes, and afterwards placed in position in the building.

Taking, for example, the Semicircular Arch, the springing line is first drawn across the top of one jamb to the other (see Fig. 71 on page 52). This line is then divided into two equal parts, the centre point being marked A, and the two points at which it cuts the jambs being marked B and C respectively. Then with A as the centre and B as the radius, the semicircle is struck. This gives the outline of the underneath of the arch.

As the arch is to be formed of one or more rings of brickwork, semicircles at a distance of $4\frac{1}{2}$ inches, 9 inches, and $13\frac{1}{2}$ inches if desired from the semicircles drawn should then be struck. The outer one of these gives the thickness of the arch, and the inner ones, half bricks and whole bricks respectively. The next step is to divide the arch into brick widths, and to do this it is necessary to measure along the outer ring or extrados the width of the brick, great care being taken to ensure that these widths do not exceed the width of the bricks after they have been rubbed. In setting out these widths the start must be made from the key brick and not from the springing line as is sometimes supposed.

The exact size and shape of this key brick is obtained by first drawing an upright line at right angles to the springing line through the centre point A, and extending it through the lower arch until it cuts the upper arch. Then divide the width of one brick and set out half on each side of this perpendicular along the outer arch. From these two points draw lines towards the centre A until they cut the inner arch.

The remaining bricks of the arch may be set out in widths of a brick on the outer ring, and lines drawn from them towards the centre until they cut the inner arch.

Traversing.—The bricks of the arch having been thus set out to full size, a wood template is then made. The template is the same width as the key brick, but 6 inches or 8 inches longer, and made out of a piece of wood $\frac{1}{2}$ inch in thickness. Great care is required in cutting this template, as any inaccuracy is multiplied by the number of bricks in the arch.

As lines drawn along the outer edge of the template indicate the actual sizes of the bricks if laid dry, it will be found that there will be a space left between the edge of the last brick and the springing line. This space should be the product of the width of the joint multiplied by the number of the joints. If the widths of the joint are $\frac{1}{32}$ inch, two straightedges each of a $\frac{1}{32}$ inch in thickness should be prepared. The template is then placed on the key again, and the battens, which should be about 18 inches long and 2 inches in depth, are then placed on either side of the template, the left one being kept up above the soffit to allow space for marking the soffit mark on the template. The next step is to hold the left-hand straightedge firmly in position. The template is then placed against the left-hand straightedge still held in position, the soffit mark on the template corresponding with the inner arch. The right-hand straightedge

Fig. 86.—PIER CAP IN MOULDED BRICK (*The Brick Builder*).

is then placed against the template, the lines drawn down the sides of the template and the straightedge giving the exact positions of the arched bricks and the joints. If this operation is repeated until the springing line is reached, it should be found that the bottom edge of the straightedges when placed against the last brick in the arch coincides exactly with the springing line, if the work has been accurately done.

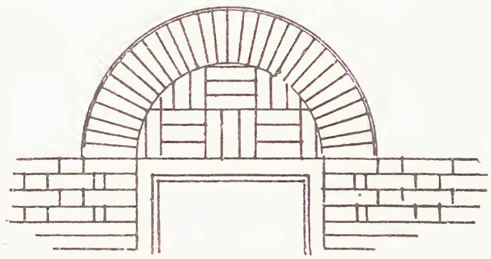


Fig 87.—Panel over door opening.

PANELLED BRICKWORK

Panels are also formed in brickwork, which, as well as adding a decorative effect, reduce the quantity of bricks in the thickness of the wall.

The sides of sunk panels, unless formed of moulded bricks, are square angled, but the sill of the panel should be formed of a bevelled brick to form a weathering.

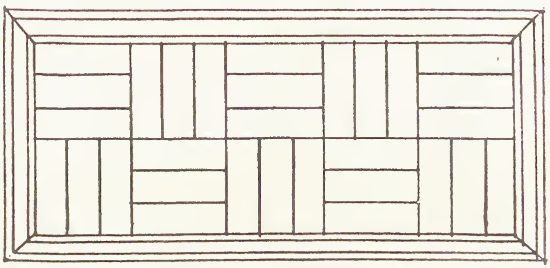


Fig. 88.—Panel in diaper bond.

The bond must be carried past the square angle, so that a straight joint does not show up the whole angle.

Panels are sometimes sunk in the surface of wide piers to give the effect of a lightness.

Over the heads of panels the bricks are corbelled out again to the original face, and in order to give a lightness to the shadow cast by this corbelling the lower corbel course may be formed of bricks set diagonally to form a zigzag pattern, or a heading course having every alternate brick flush with the face of the panel to form a toothed or dentil course.

Fig. 89.—Blocked indented quoins.

QUOINS

To provide additional decoration, and at the same time to give the effect of strength, quoins are formed at the angles of buildings in the following manner.

Projections three bricks in width and five courses in height of $1\frac{1}{4}$ inches are formed, having between them single courses flush with the surface of the main walling.

Fig. 90.—Brick panels in timber framing. The panel on the left is in herring-bone bond.

Courses of a similar nature are also formed under the eaves and over the heads of the windows at the different floor levels, when they are known as String Courses.

Ornamental brickwork in moulded bricks is also achieved in the form of *Hood or Label Courses,* as seen in Mediæval architecture. Window sills and cornices are also to be obtained all ready moulded from the makers.

In these last details, however, in modern work, the moulded brick has been for the most part superseded by stone and terracotta. The actual additional work required in rubbing and jointing renders the work too expensive for any but an enthusiast in brickwork.

In the formation of gables, however, there are possibilities in which the use of decorative brick may still be employed at its best.

CHIMNEYS

That portion of the chimney which extends above the roof generally described as the chimney stack affords opportunity for economical decorative effect in the hands of a sympathetic designer.

It is customary to form the upper courses of a brick chimney so that they project from the main surface of the chimney below. The main reason for this is to prevent the water from running down the surface of the

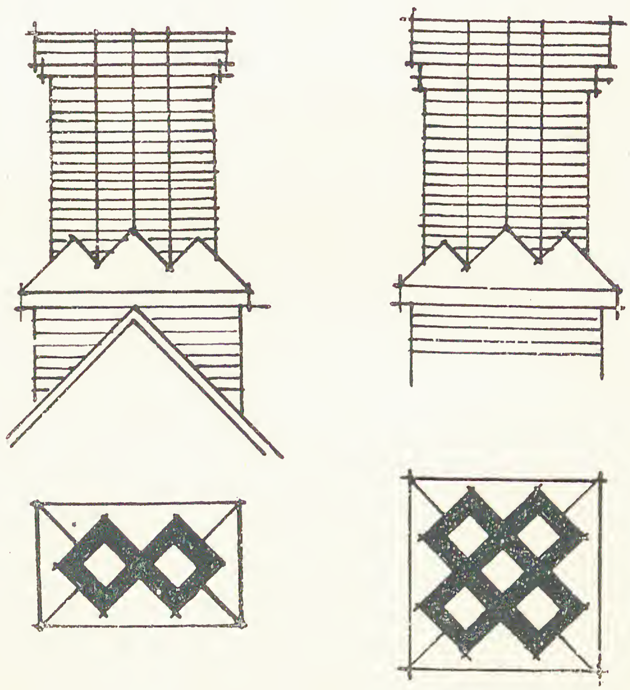


Fig. 91.—Diagonal chimney stacks.

brickwork, and not only causing stain, but what is more serious, rendering the brickwork damp, which is one of the causes of smoky fireplaces, and one which it is most difficult to overcome.

The simplest form of projecting chimney cap is one formed of two or more Oversailing Courses, projecting $2\frac{1}{4}$ inches, and having beneath them a single course, which may be a dentil course of $1\frac{1}{4}$-inch projection.

A similar effect is to be obtained without any actual projection by sinking a course at a height of about five courses from the top, and it is

Fig. 92.—Example of fireplace in brick by Elliotts West Howe Pottery.

an important structural point to note that the top courses of chimney caps, where they are not either of moulded bricks or stone, should be constructed of brick-on-edge set in cement.

Whilst the moulded and diaper-patterned chimney stacks, such as may be seen at Hatfield House, in Hertfordshire, are now prohibitive, mainly by the cost of labour, a similar likening of effect is to be obtained by forming the chimney stack above the roof with each flue built diagonally to the main line of the chimney stack. The flues may be constructed actually separate in this manner, or their inner angles may be joined together.

TERRACE WALLS AND GATEWAY PIERS

Many fine examples of piers to large and imposing entrances and gateways, and of terrace walls built in brickwork, are still to be seen throughout the country, and the combination of a brick pier having raised panels with stone base and cap forms an imposing spectacle.

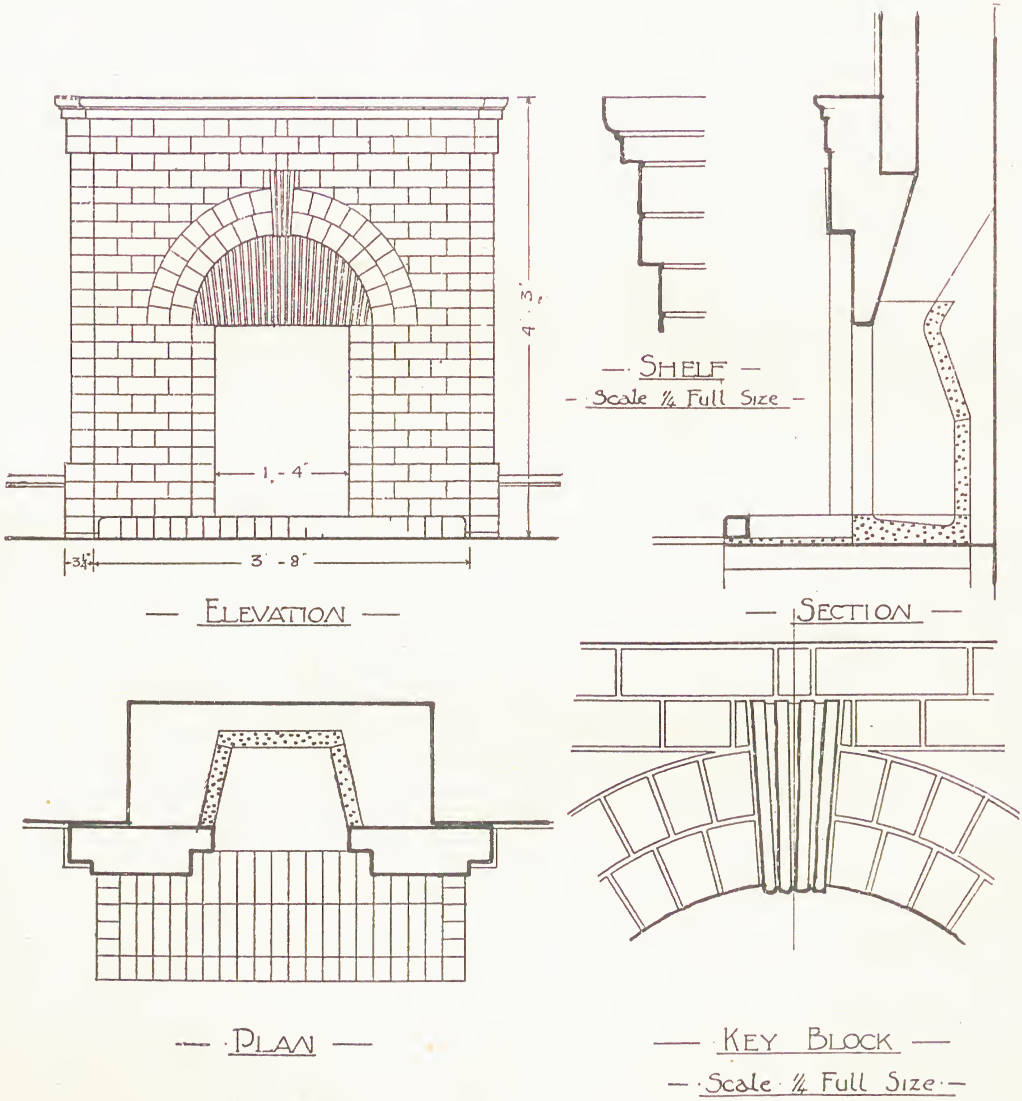


Fig. 93.—Fireplace in small bricks.

It is no longer economical to build large and extensive boundaries in brickwork, but short walls round forecourts may be constructed either in diaper or openwork pattern. The latter, though of only half a brick in thickness, will be found of considerable durability if set in cement.

FIREPLACES IN BRICK

Very decorative effects are to be obtained in the interior of rooms by forming the fireplace and overmantel of brickwork.

This practice has been so much popularised of late, to the extent that wooden and cast-iron fireplaces have been superseded, that certain manufacturers have specialised in the supply of bricks for this purpose alone.

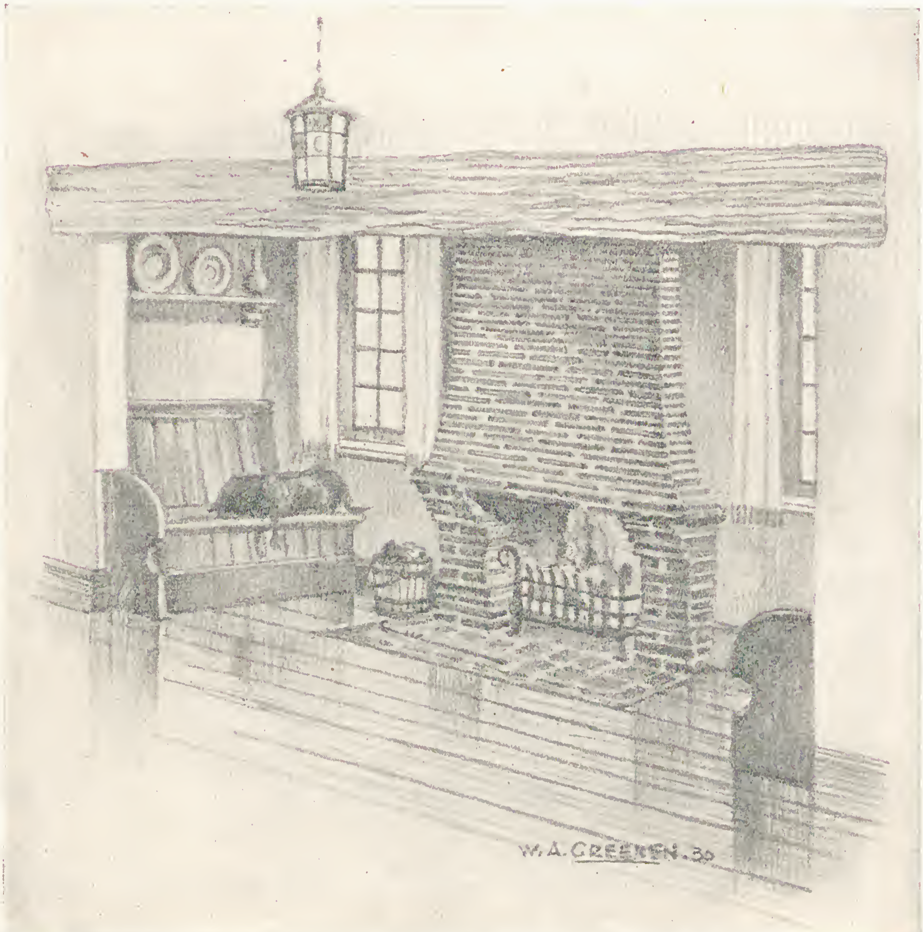


Fig. 94.—Example of fireplace in brick by Elliotts West Howe Pottery.

The main point of these fireplaces is that whilst being decorative mainly on account of the patterning and varied colours of the brickwork, they are composed for the most part of plain surfaces, rather than mouldings, and are therefore economical to build and cleanly in use (Figs. 93, 94, 95).

The main economy in their construction lies in the fact that the chimney stack itself being constructed of brickwork, this same brickwork built

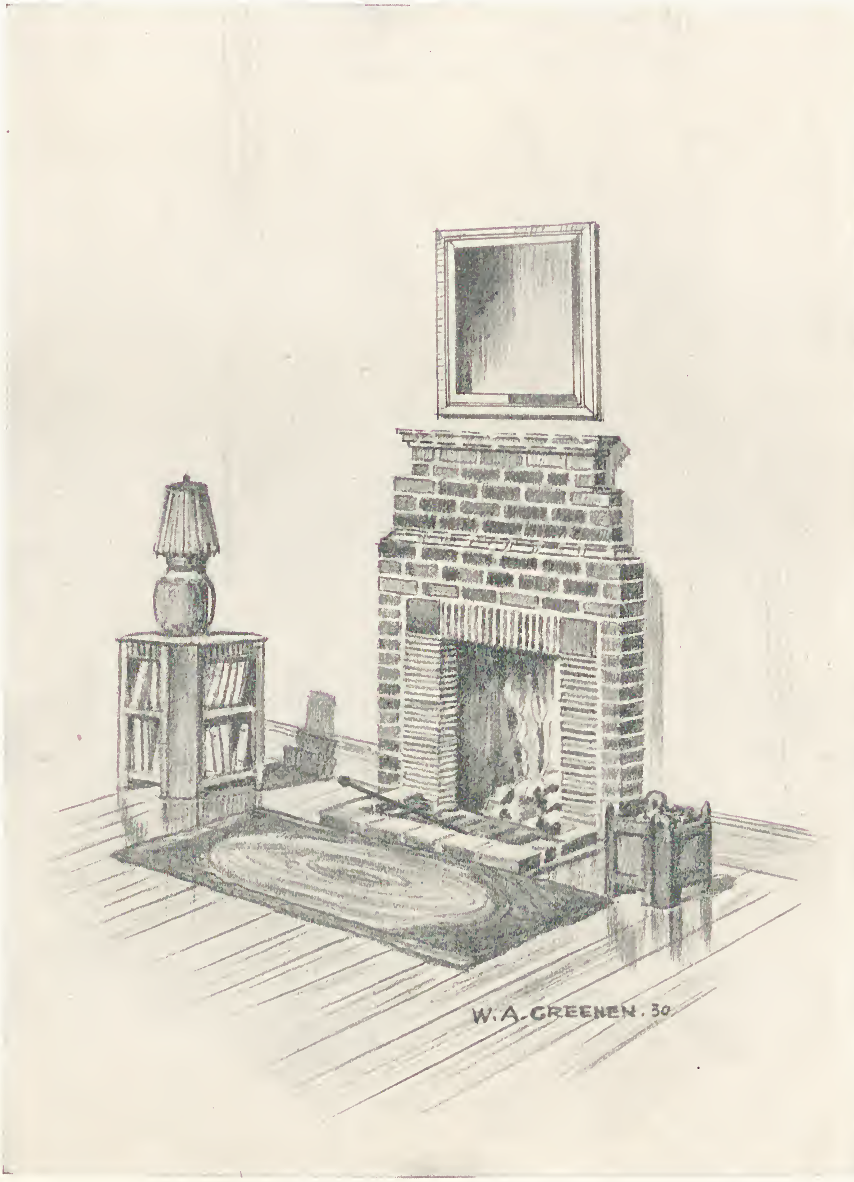


Fig. 95.—Example of fireplace in brick by Elliotts West Howe Pottery.

into artistic shapes is made to form the actual fireplace and overmantel without any additional fitment of wood, marble, or metal.

The actual fireplace interior may be constructed of fireclay brick, or a special cast fireclay interior known as the West Howe Fire is to be obtained. This is made in two pieces, comprising a fire bottom and back designed from specially selected clays, which have been found to be specially heat resisting, and the angles at which the fire back and bottom are set afford the maximum radiation, and the most perfect combustion. The well of the fire bottom falls sharply in the front and rises gradually

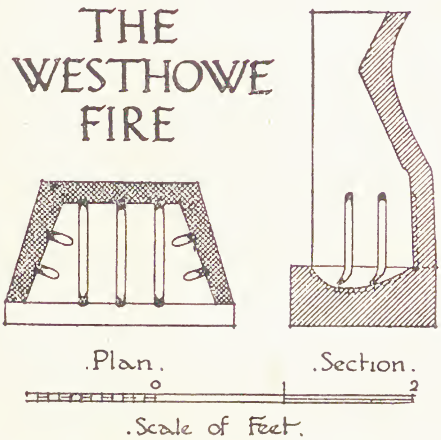


Fig. 96.

at the back, by which means the accumulation of dead ashes is avoided. The simplicity of erection is ensured by the fact that this interior consists of only two pieces.

Special shaped bricks are to be obtained for forming almost any required angle or formations, such as hexagonal columns or moulded shells, in conjunction with these interiors.

CHAPTER 3

BRICKWORK—FIREPLACES AND FLUES

CONSTRUCTIONAL DETAILS

THE *excavation for the foundations* and the laying in of the footing, should be undertaken at the same time as for the rest of the buildings and unless there is any excessive weight or other reason, these will be of the same depth and spread.

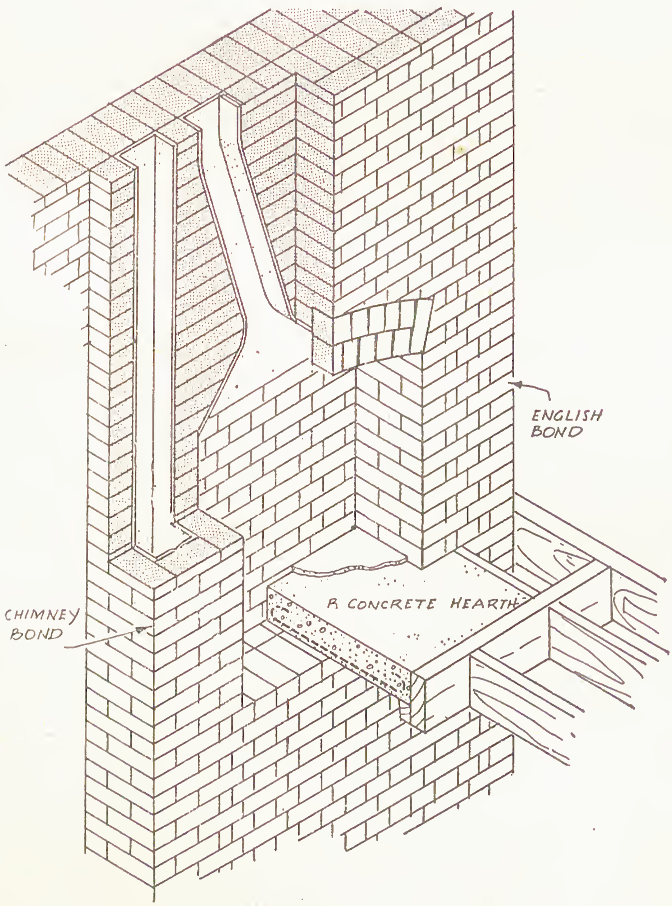


Fig. 97.—Upstairs fireplace and flues with brickwork cut away to show construction.

A greater spread may be necessary if the chimney is an external one, when it will lack support from the building, and be more likely to suffer from overturning movement occasioned by wind pressure.

It is very important that the erection of chimneys should proceed at the same rate as the walling of the main building and not be built in advance, and bonded in afterwards.

The materials of which flues are constructed must be incombustible, and brickwork set in good mortar with the flues properly parged is the most satisfactory material.

The by-laws demand that every fireplace shall have its own flue, and that this flue shall be continuous from the fireplace to the top of the chimney and have no communication with any other flue.

This intercommunication of flues is more often seen than might be expected, with the invariable result that the fireplaces smoke.

The size of flues to the rooms of ordinary dwelling houses is 9 × 9 inches, and for the average-size fireplace this is the best size. Some flues are 13½ × 9 inches, but it would not seem that they have the support of scientific principles, as such an area gives a body of cold air of too great cubic dimensions for the heat to raise it at the required rate to prevent the fire from smoking.

The size of 13½ × 9 inches is suitable for exceptionally large fires, as in hotel and canteen ranges.

It is demanded by by-laws that the wall surrounding any flue should not be less than 4½ inches thick.

It is customary to construct the opening into which the fireplace interior fitting is built of two jambs, which project into the wall and are arched over to support the brickwork above, the whole forming what is termed the *chimney breast*.

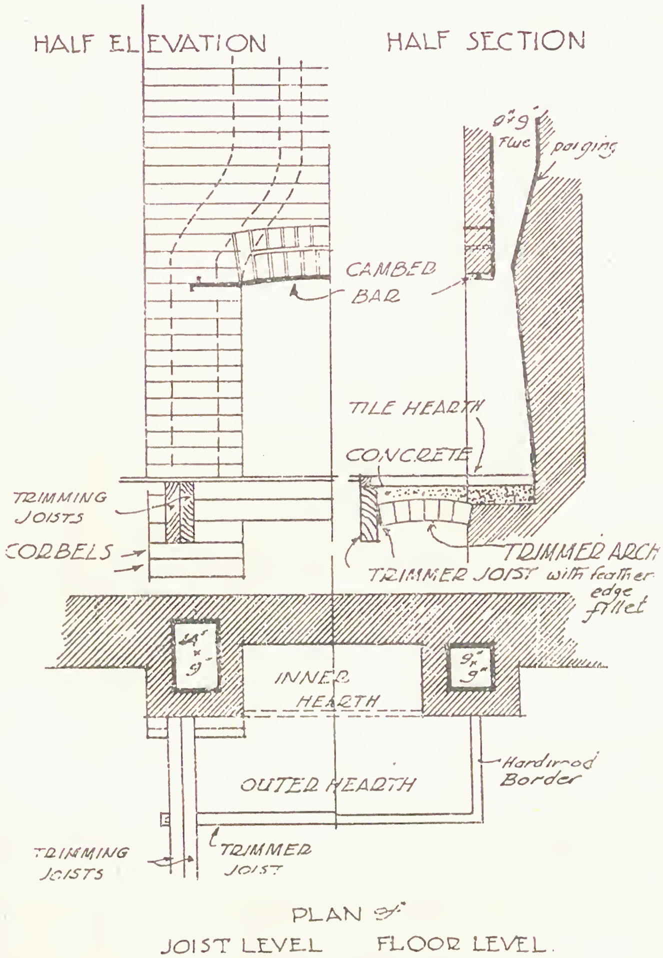


Fig. 98.—Details of hearth construction.

The dimensions of these openings, both height and width, have been diminished in modern practice, owing to the fittings which have been placed into them having been considerably reduced in size. For instance, the kitchen range, which in the old days was rarely less than 6 feet wide, is now accommodated in an opening of 4 feet 6 inches in width, though the height still remains in most instances at between 5 feet and 6 feet. So small an area as 1 foot 6 inches wide by 2 feet 6 inches in height may be found quite sufficient for ordinary living-rooms, and even less for bedrooms, but the deciding factor will be the size of the fireplace fitting which has been chosen.

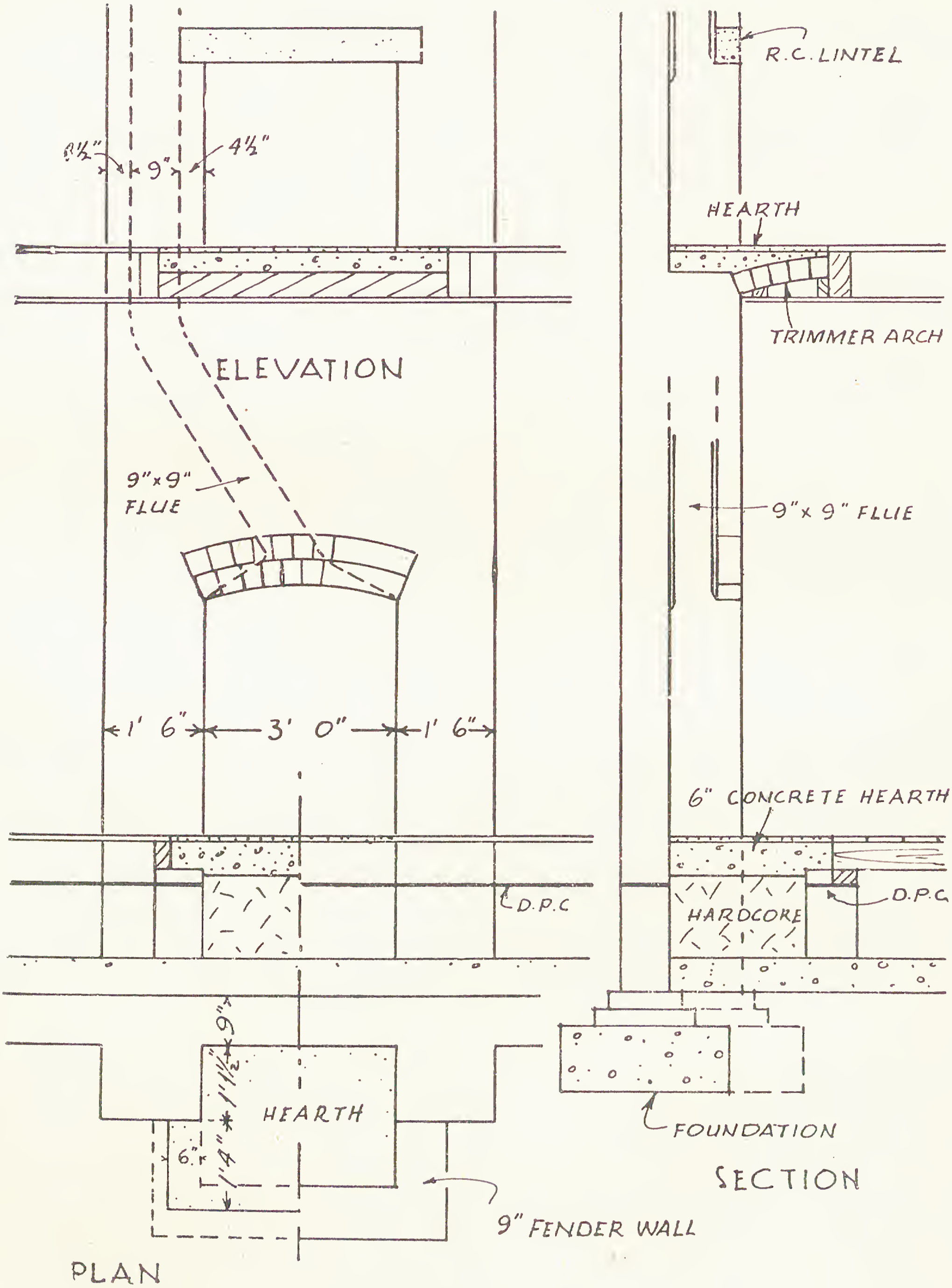


Fig 99.—Fireplaces and flues.

Hearths.—The construction of the hearth is an important matter with regard to the prevention of fire. On the ground floor, where the hearths may be of concrete cement faced with stone, or brick on edge, they should be supported and surrounded by a fender wall $4\frac{1}{2}$ inches thick built on proper footings, and it is important that the back of a fireplace, wherever it can be managed, should be built in 9-inch brickwork. Where two fireplaces come back to back, and the interiors are supplied with good thick fireclay backs, this is perhaps an unnecessary precaution (see Fig. 102).

Trimmer Arch.—The hearths to fireplaces on the upper floors are generally supported by an arch which is termed the *Trimmer Arch.* This arch is turned from the face of the brick wall to the trimmer joist, which runs across the front of the hearth, and it may have the two springings at the same level, or spring from a lower level on the wall to a higher level on the trimmer. It is generally formed of brickwork, the skewback being cut into the wall at an angle and a feather-edge fillet forming the skewback on the trimmer.

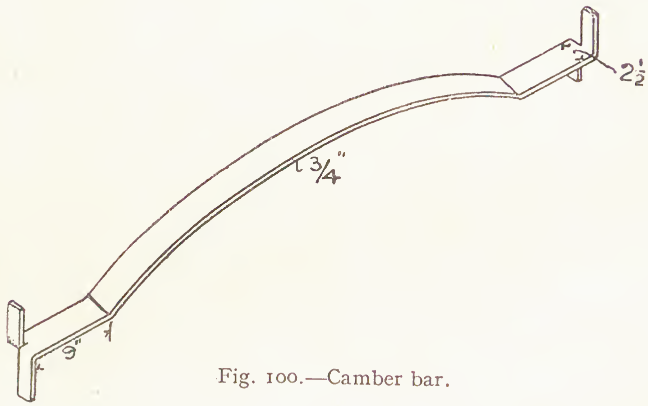


Fig. 100.—Camber bar.

On the top of this arch is laid the concrete, which forms the hearth, and the surface of this is floated in cement, which may be the actual finish or be covered with glazed tiles. The concrete filling must be continued right into the back of the fireplace opening.

A 6-inch reinforced concrete slab is now more frequently adopted.

A special steel bridge as a substitute for this arch, known as Moore's Steel Bridge Plate, is manufactured, which has one edge turned up for nailing to the trimmer, the other end being supported by a 3 × 2-inch bearer, and resting on the brickwork of the back hearth.

Cantilever Sub-hearth.—In positions where there is not sufficient support from below, a cantilever sub-hearth is formed in either stone or concrete. This form of construction is particularly suitable for fireplaces which are run across the corner of a room, having no support from below other than that afforded by the two outside walls.

The internal construction to the hearths to the downstairs rooms is as follows :

The space formed by the fender wall and the fireplace opening is filled in with hard-core filling and over this is laid the 6-inch concrete sub-hearth covered with a floating of cement, finished with a smooth surface on which if required glazed tiles are laid.

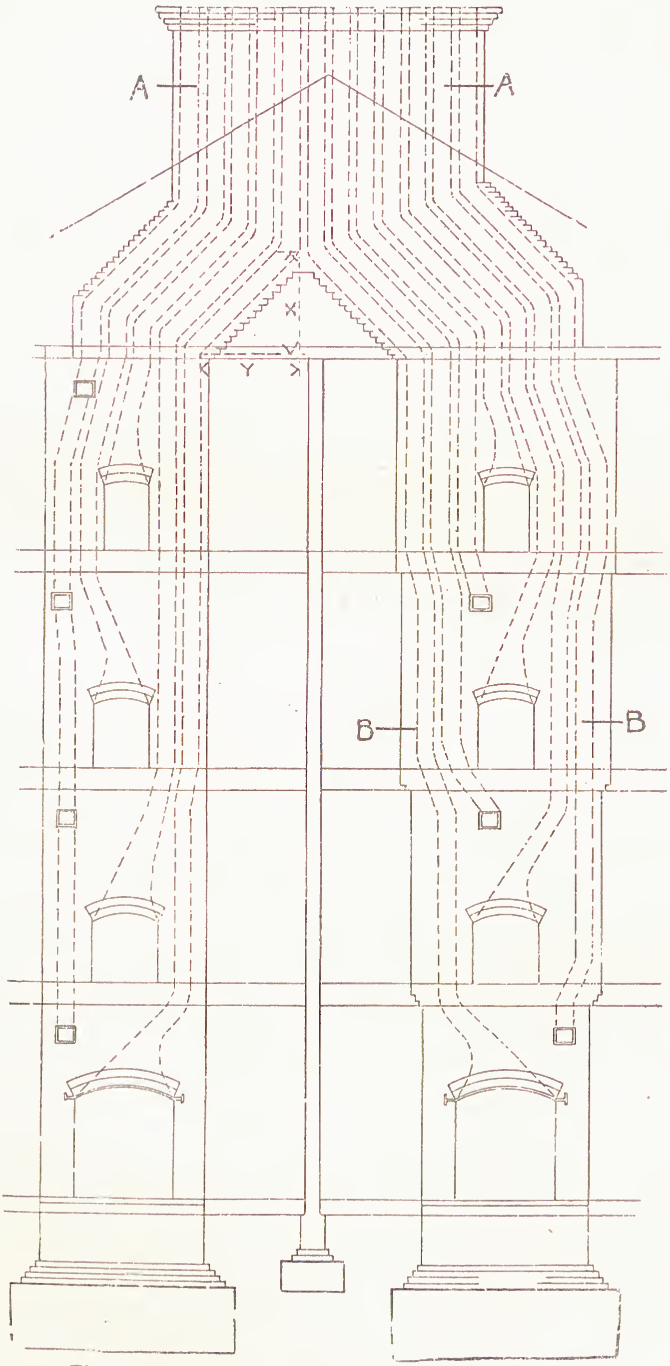


Fig. 101.—Two sets of flues gathered into one stack.

These sub-hearths for ground-floor rooms may also be supported on 3-inch stone slabs, or the concrete may be reinforced with steel reinforcement of $2\frac{1}{2} \times 2\frac{1}{2}$-inch steel T bars reversed and at 10-inch centres, the space between these T bars being occupied by 9×9-inch tiles.

The Fireplace Opening.—The sides of the fireplace opening are built up in 9-inch or $13\frac{1}{2}$-inch piers, bonded to the main wall, and the back is offset from the foundations until a 9-inch thickness is reached. The top of the opening between the two jambs or piers is closed in by a two-ring Rough Brick Arch, built on the face of the wall, and the walling above continued up flush with the face of the two side piers. To carry the rough arch just mentioned a $2\frac{1}{2} \times \frac{1}{4}$-inch wrought-iron chimney bar, bent to the required rise of the arch, generally about 3 inches, is built into the brickwork of the jambs, having its ends cut and turned up and down to fit into the joints in the brickwork. Behind the arch the brickwork is gathered over in order to reduce the size of the space behind the arch to the size of the flue required as quickly as is in conformity with sound constructive and scientific principles.

This chimney bar is also called a *camber bar* (Fig. 100).

The thickness over the arch and the arch itself is only $4\frac{1}{2}$ inches. This leaves a space of 9 inches in the depth of the $13\frac{1}{2}$ inches fire opening which gives the required dimension of the flue from back to front. It is now required to reduce the size of the opening from the width of the interior of the fireplace to 9 inches, which is the other required dimension of the 9 × 9-inch flue.

Gathering Over. — The operation necessary to do this is termed gathering over, and it is perhaps the most important operation in the construction of a flue, for whilst it is necessary to arrive at the dimensions of the flue as quickly as possible, the actual work of reduction must not be done in such a manner as to afford lodgment or to form too acute angles on which either soot may collect or the passage of the smoke up the chimney be obstructed.

The gathering over is achieved by building in corbel courses of bricks having splayed ends, so that a curve is formed in the flue, having a smooth and continuous face over which the parging is spread.

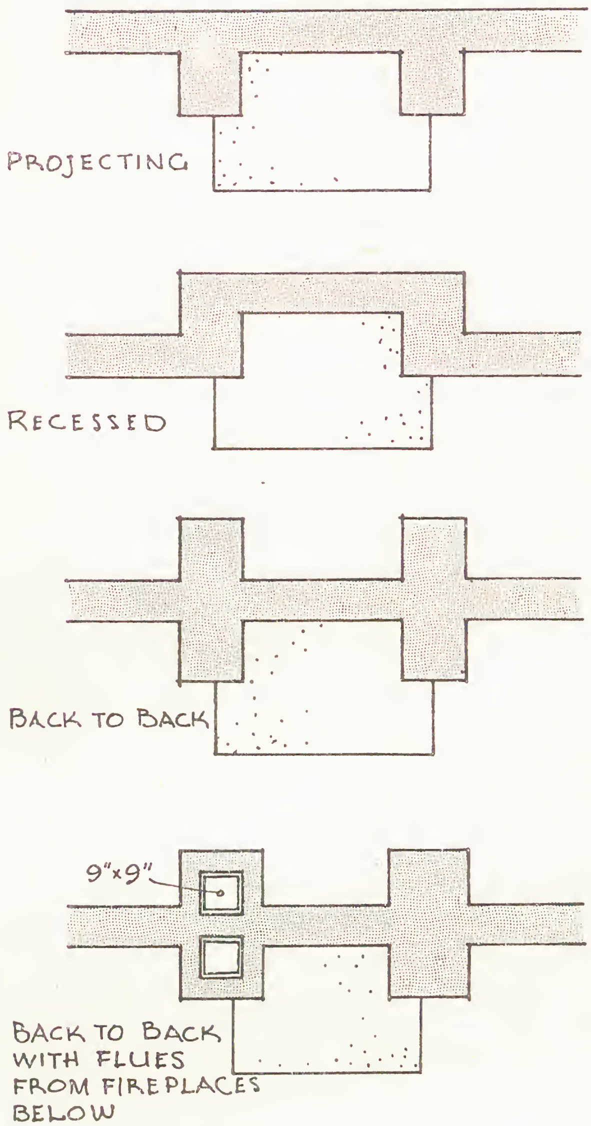


Fig. 102.—Plans of fireplaces.

The flue is generally led to one side of the chimney breast in order to provide space for the fireplace opening in the room above; that is to say, that as one stands facing the fireplace opening, one gathering over is led away to one or the other sides of the chimney breasts, until a thickness of brickwork of only $4\frac{1}{2}$ inches is left between the flue and the side of the chimney breasts. The brickwork forming the other side of the flue is gathered over in the manner already

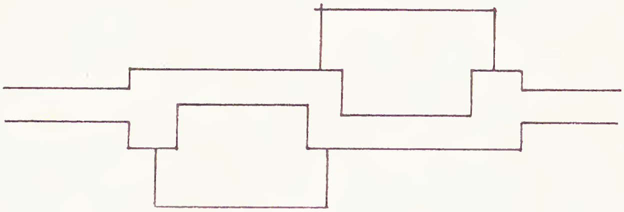


Fig. 103.—Interlaced or side-by-side fireplaces.

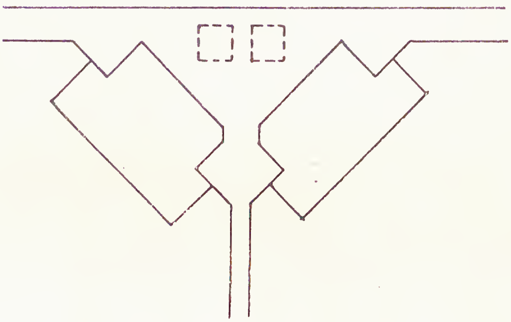


Fig. 104.—Pair of corner fireplaces.

described towards the side already formed, and is carried up vertically at a distance of 9 inches from the other side.

The general rule with regard to the angles of these gatherings over is that they should never be executed at an angle of less than 45°. To gather over at an angle of less than this is to oppose the passage of the smoke with a surface that is too near the horizontal.

Lintels for fireplaces are often substituted for the rough arch and camber bar. These in old work were formed of wood, but are now prohibited by the by-laws. They should be of reinforced concrete. But where concrete is used for the Lintel it may be carried back for the whole depth of the opening, and the flue with gatherings over cast in the concrete lintel. This saves a very considerable amount of work in cutting bricks to the proper angle, and forms a very satisfactory chimney from the smoke-discharge point of view.

Cast-steel Lintels are also to be obtained in which the gathering over and flue are all arranged for, though it is perhaps inadvisable to use these for any openings wider than 2 feet 3 inches, as the constant expansion and contraction in a large surface of metal is liable to cause fracture in the brickwork surrounding it.

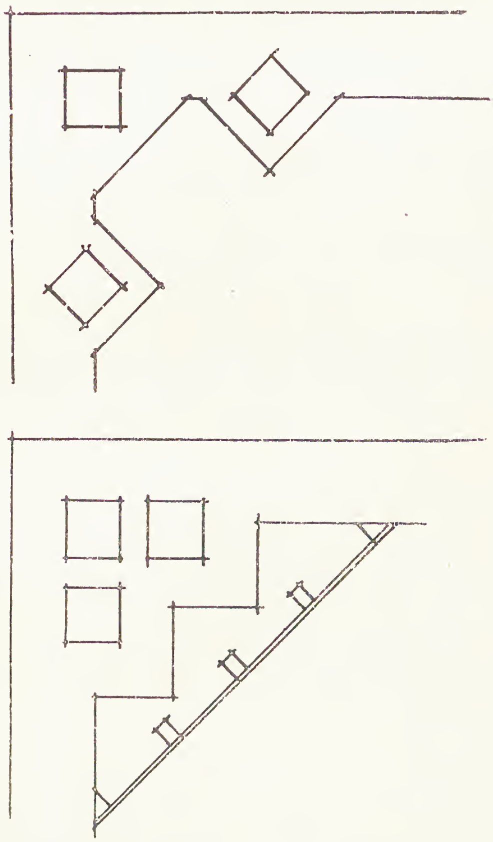


Fig. 105.—Corner fireplaces and flues.

Parging.—As the work of building up the flue proceeds the inside faces should be lined with a rendering coat, which may be composed of lime mortar, mixed with cow dung in the proportions of 3 to 1, or of Portland cement mortar from $\frac{1}{2}$ inch to $\frac{5}{8}$ inch thick. The surface should be well trowelled and rounded at the corners and interior angles.

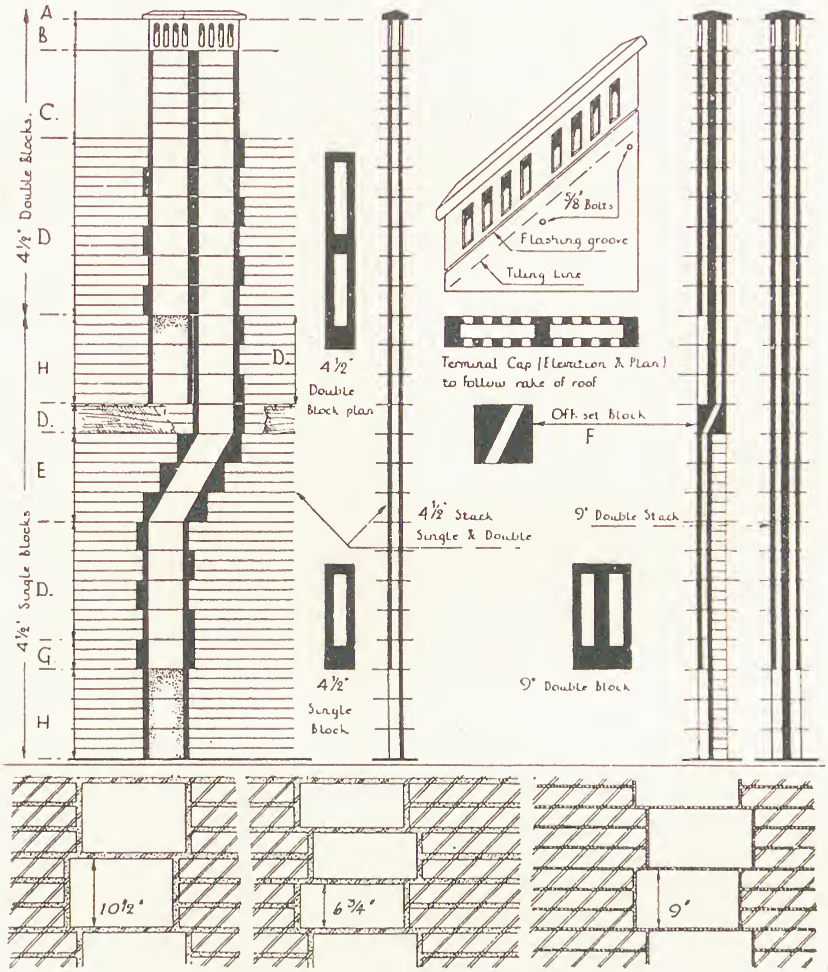


Fig. 106.—Vinculum gas-flue blocks.

The specification, besides requiring the flues to be parged, will also require that they should be *cored.* This term means freeing them from all projections of mortar or fallen pieces of brick. It is performed by attaching some sacking stuffed with straw to a rope with which it is pulled up as the work proceeds. Any droppings of brick or mortar which it has collected are then removed, and it is important to see that the sacking is a fairly tight fit in the flue-room.

Flue Linings are also to be obtained ready made in earthenware pipes either square or circular. With these are supplied bends for the angles and a purpose-made funnel to fit down over the gathering in. Should the angles be of such a degree that there is difficulty in obtaining them in the earthenware linings, they may be formed in cement mortar. Flue linings are better than pargetting—heat causes the latter to crack in a short time.

Gas-fire Flues.—For gas fires special pre-cast flue bricks are supplied which, having the flue inside them, may be built into the thickness of the wall without requiring any chimney breasts. Two types are illustrated in Figs. 106 and 107.

An important point with regard to gas fires, more frequently overlooked than should be the case, is that there must be a flue to every gas fire. But the ordinary 9 × 9-inch flue built for the coal fire is too large for the products of combustion of a gas fire, 9 × 2¼ inches giving quite a sufficient area.

Chimney Caps.—A chimney should, wherever possible, be carried up above any roof in its immediate neighbourhood, as this avoids smoky fire resulting from down-draught, caused by the winds deflected from the roof down the chimney.

The cap itself is generally formed by oversailing courses in the brickwork, a simple form of cap having the four top courses corbelled out 2¼ inches, and the course immediately below corbelled only 1⅛ inches. The purpose of this projection is to enable the water collected on the top of the stack to fall without running down the surface of the brickwork, and so unduly wetting the brickwork itself. A damp flue has the effect of rendering the air within the flue so cold that it sinks and causes the fireplace to smoke.

Though it cannot be denied that the square stack is the cheapest form in which a stack can be built, yet a lightness can be given to a stack, especially where it contains several flues, by building in its upper portion with the flues placed diagonally to the square of the chimney below. For economy, as many flues as can be, without creating in them too acute angles, should be grouped together into one stack. It is often found possible to bring the flues from the opposite sides of a house together in one stack in the space between the ceiling of the top floor and the roof.

Though there is no real necessity for a chimney pot, yet it has become such a customary practice that to some a chimney stack without a pot appears unfinished. The real purpose which the chimney pot serves is the formation of a check between the flue itself and the outer air. This is brought about by the diminution of the area of the interior of the pot. Consequently this purpose will be as readily effected if the pot be sunk in the brickwork of the chimney, instead of being allowed to stand upwards into the air in a manner which to many is extremely unsightly.

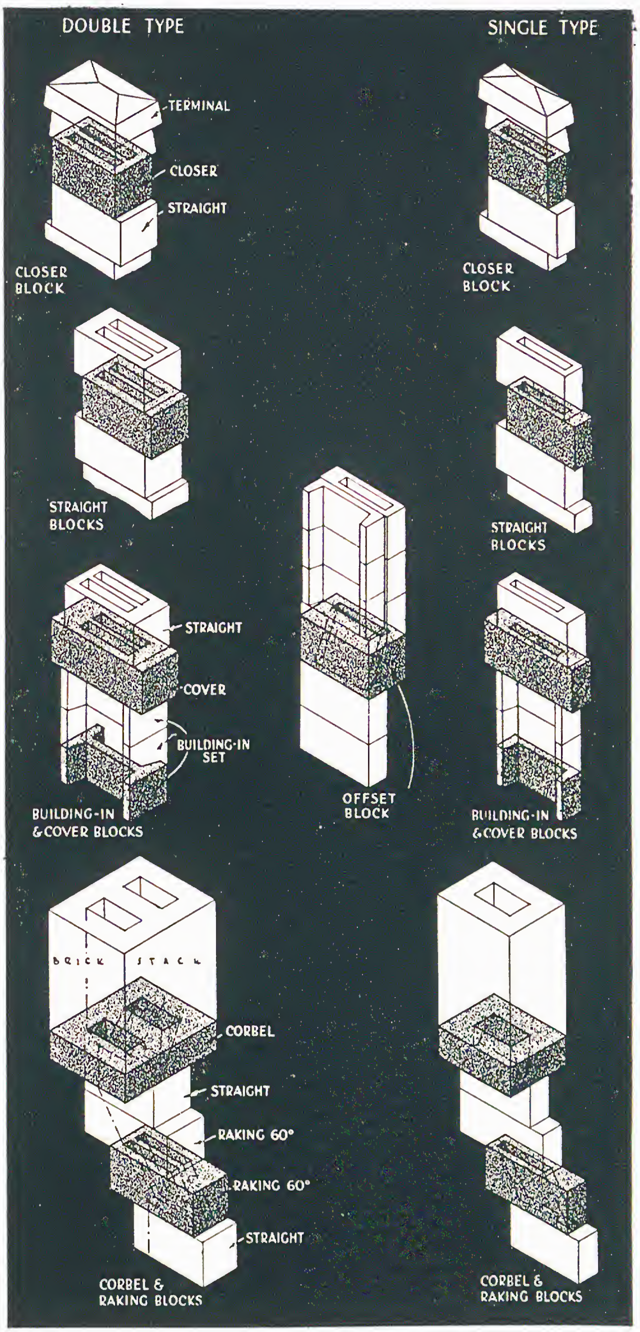


FIG. 107.—NAUTILUS GAS-FLUE BLOCKS.

Flaunching.—Whether the pot is stood on the top of the brickwork or whether it is sunk into the brickwork, as last described, the top of the chimney should be covered with a coating of cement sloped away from the pot to the outer edge of the cap. This is termed the flaunching. Any other projecting courses, either in the stack or in the outer surface of the chimney itself, should have sloping surfaces formed on them in cement to lead the water away from the brickwork. The underside of projecting courses should, wherever possible, be *throated* to prevent the water from running backwards.

A very efficient type of terra-cotta chimney pot is one cast with a base $10\frac{1}{2}$ inches square which fits down on top of the 9×9-inch flue. The upper portion is turned circular, and brickwork and cement are built up around this pot, allowing not more than 6 inches to show above the surface of the cement flaunching.

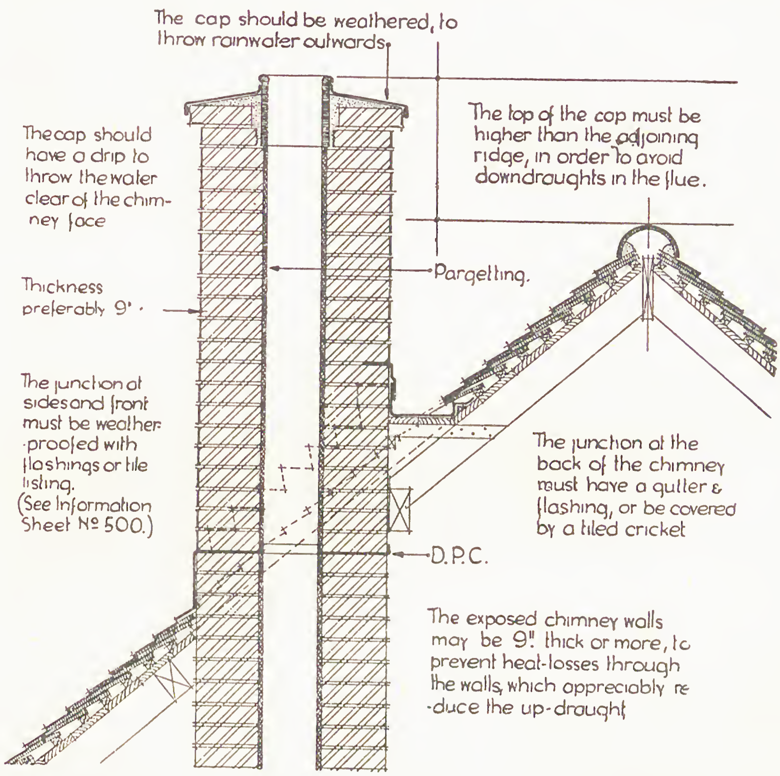


Fig. 108.—Features of good chimney construction.
(Courtesy of *The Architects' Journal*, Library of Planned Information.)

A point worthy of interest is that any projection given to caps or string courses in chimney stacks should be made less than might be supposed, to give a pleasing amount of projection when seen on the sectional drawing. This is accounted for by the fact that this projection is never seen in section, but is very noticeable when seen at an angle; that is to say, the projection seen at the corner of the chimney is considerably increased from what it was when drawn in section. Especially is this noticeable where the chimney is formed in its upper portion diagonally to the main walling of the chimney below. The correct way to get the right amount of projection is to draw the chimney diagonally, and to give the oversailing courses at the angle the projection that looks in good proportion, even though this when drawn in section may appear too little.

Points in the Construction of Flues.—In chimney stacks which are to have a brick facing where possible the bond should be the same as that to the main walling of the building. Where the external walls of the chimney stack are only $4\frac{1}{2}$ inches thick, chimney bond is the strongest, as shown in Fig. 109.

It is always advisable to have at least one outer wall of the chimney stack 9 inches in thickness. The partitions between the flues are called *Withes or Mid-Feathers*. These should be bonded on alternative courses on the stack walling.

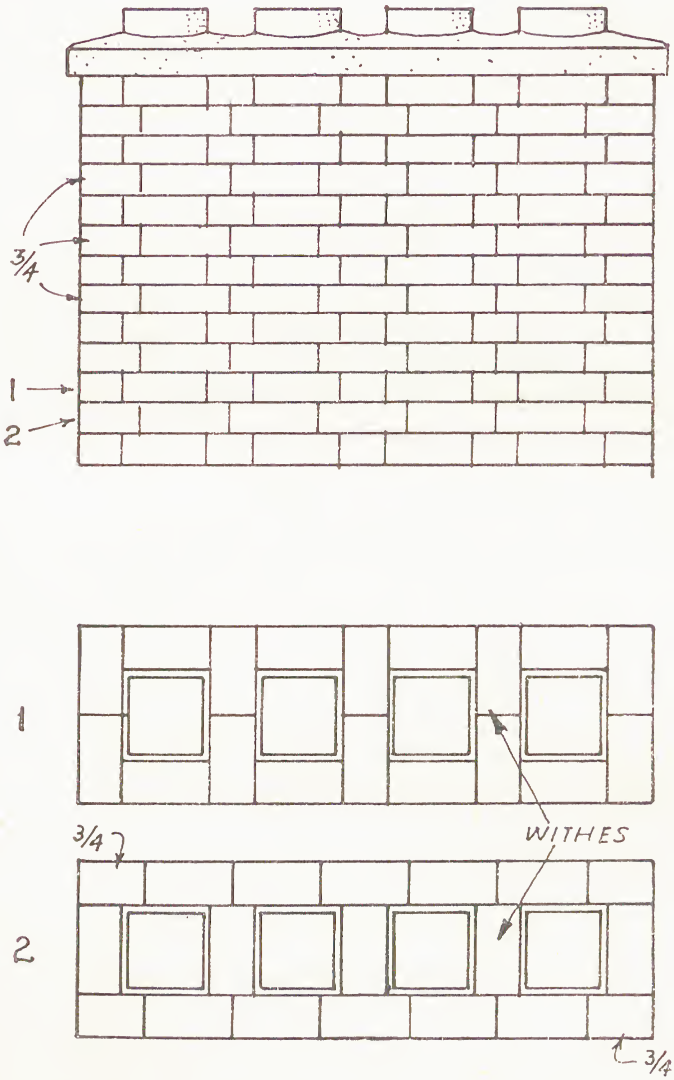


Fig. 109.—Chimney bond in $4\frac{1}{2}$-inch brickwork.

Where flues must be constructed at a lesser angle than 45° soot doors and frames should be built in at the bottom of each straight run, to enable the flue to be swept periodically and any obstruction which may have collected in the bends removed.

Chimney stacks should be rough rendered with cement rendering where they pass through floors or roofs as a preventive against fire. It is advisable to build the whole of the chimney stack above the roof in cement.

In no instance must the chimney breast be cut into to receive the ends of any joists, beams or rafters. Many instances of fires which have broken out in old houses have owed their origin to the fact that a main beam has been let into the chimney breast, and in some instances even run right across the flue. These beams at last becoming ignited will smoulder for a long time before the fire actually breaks out.

Dampcourses in Chimneys.—The dampcourses to the main walling of the building should be carried continuous over the foundation walls of the chimney. There should also be another dampcourse at the point of intersection of the chimney with the roof. This is especially necessary in districts where the local brick is of a porous nature. The omitting of this dampcourse is frequently the cause of the appearance of damp at points which, when seen from within, seem to be most unlikely, that is, in the chimney breast near the ceiling.

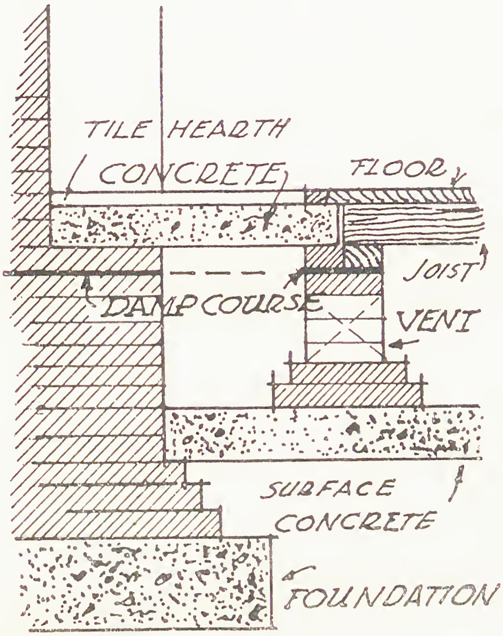


Fig. 110.—Damp-proof course under hearth.

Flashing and Jointing.—The angles formed by the roof and the vertical surfaces of the chimney stack must be protected against the rainwater collected on the roof (Fig. 112). This is effected by filling in the angle with flat strips of lead or zinc cut to necessary shape, as is explained later in Chapter 14 of this volume. The flat strip which is laid on the roof is termed *the Soaker*, and the shaped strip which is fixed against the brickwork vertically is called the *Step Cover Flashing*.

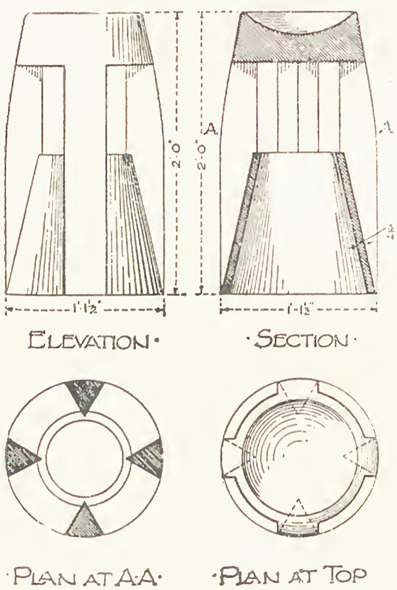


Fig. 111.—Down-draught prevention. The Edwardian pot.

The horizontal joints of the brickwork are scraped out to receive the cover flashings, which are let into them, wedged with lead wedges, and pointed up in cement by the bricklayer. This ensures that no water can penetrate through the straight joint caused by the junction of the roof.

A similar protection is afforded by the running of a cement fillet in this angle, though it has been found that there is a certain amount of shrinkage which in time causes the cement to pull away from the brickwork and so render the stoppage ineffective.

Where a chimney is roughcast or plastered, the lead flashings should be continued up under the roughcast.

Chimney Stacks in Hollow Walls.—Where the main wall of the house is constructed of hollow wall it is essential that the hollow should be

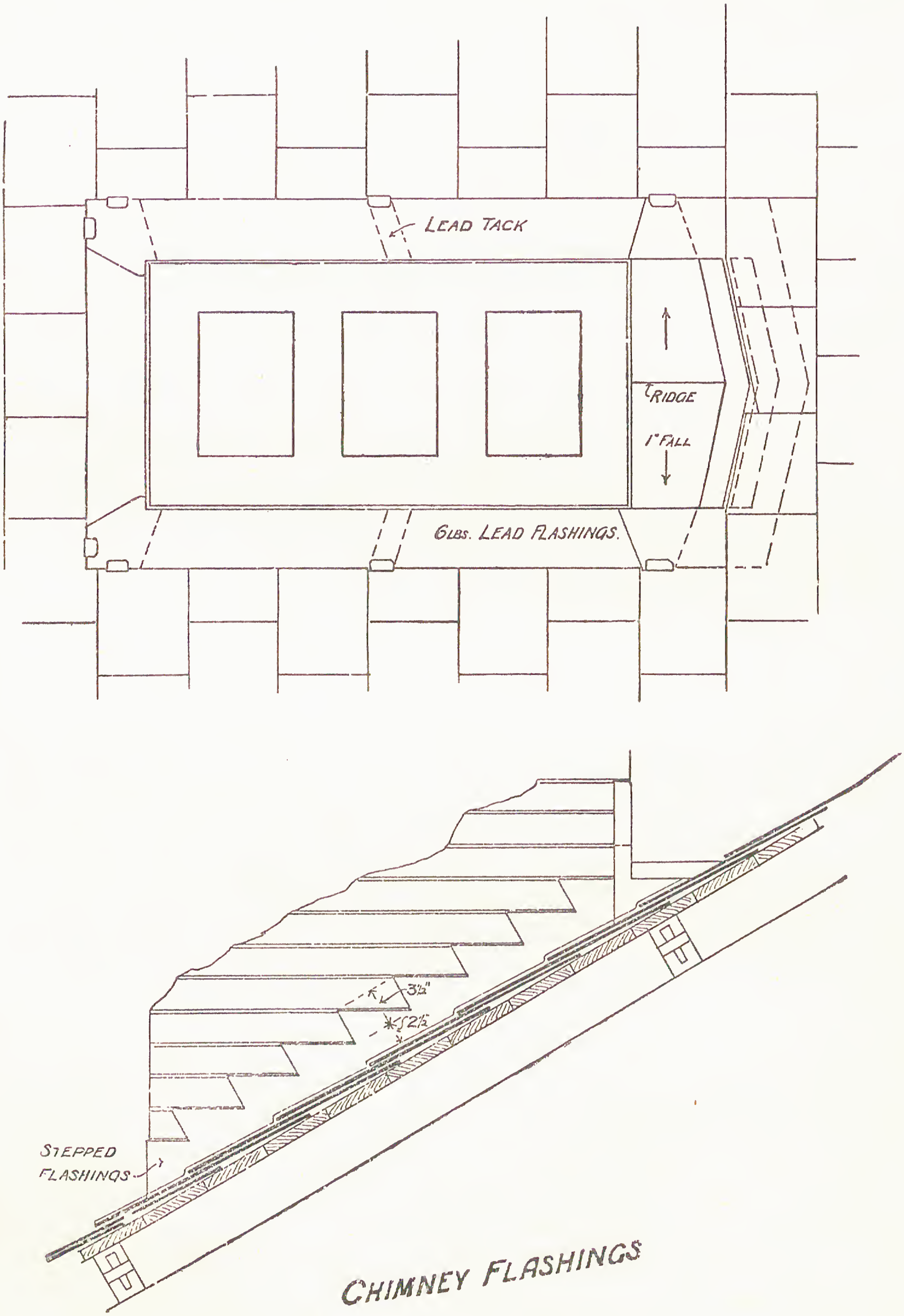


Fig. 112.—Flashing to chimneys

carried around the chimney stack where the stack forms a projection on the outside walling. In its height a hollow will be terminated where the chimney stack encounters the eaves.

Down-draught Prevention.—There are several devices for overcoming down draught in chimneys. The causes of down draught are discussed later under the heading Smoky Chimneys and Remedies. Of special-made pots, one of the most effective is known as the Edwardian (Fig. 111). One method of preventing down-draught is to cover over the top of the opening so as to offer an obstruction to any air currents tending to descend vertically. Such currents may be caused by high ground, trees, or a high roof, in close proximity to the chimney stack. For this reason the tops of these down-draught-preventing pots are slabbed over solid with a flat top. The solid top in the Edwardian pot is dished in order to give an outward trend to any direct downward air current. The result of this outward turning of the air sets up an upward suction all round the top of the sides of the pot. And as the openings from the flue are at the sides of the pot the upward draught in the flue is thereby increased. The flat dished top referred to is supported by four columns. These columns are triangular in plan, having the apex of the triangle facing inwards. The purpose of this formation is to break up and deflect cross winds in such a manner that a further suction is set up and the upward draught thereby additionally increased. The solid surface of the lower portion of this patent pot is inclined inwards and upwards, affording yet another surface for the deflection of the wind into the desired direction.

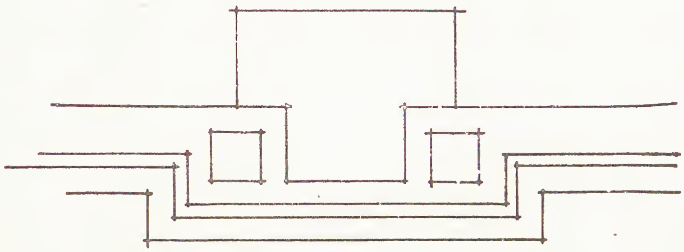


Fig. 113.—The fireplace in a hollow wall.

Revolving Cowls.—The purpose which is served by revolving cowls and other irregular and ugly shapes are all better served by the pot just described. Consequently there would seem to be no real need for these.

Alternative methods of finishing the chimney cap: the walling of the chimney is built up in the form of a gable at each end, roofed over with tiles and ridge; ventilated gratings are fitted in the side walls of the chimney stack under the eaves of the small roof above. There thus being two gratings to each flue, one on either side of the stack, a cross draught is caused over the top of the flue which has an upward suction and any down draught is prevented gaining admittance by the small roof above. Similar effects are gained from chimney caps cast in concrete, having vertical sides covered by a flat cast top, the ends being left open, or by cast semicircular tunnel-like caps.

The American Fireplace.—A practice which is followed in America might be introduced in this country to great advantage where there is a basement. The American fireplace is constructed with an ash dump in the inner hearth, which gives access to a flue communicating to an ash pit within the brickwork of the chimney stack, and having an ash door for access to the pit from the cellar below. This simple construction saves considerable housework, in that it enables the ashes from the fire to be dropped through the ash dump and into the ash pit, from which they require to be removed occasionally.

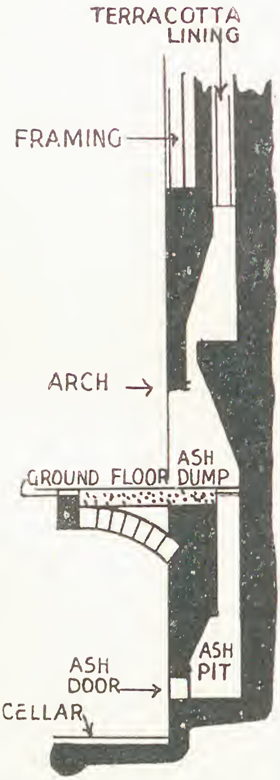


FIG. 114.—The American fireplace.

General Notes.—Chimneys which are short should be of smaller internal dimensions than taller chimneys.

Chimneys in an outside wall are more liable to become damp and to cause smoky fires than those built on an inside wall. Consequently, the back of the chimney should wherever possible be 13½ inches thick, unless the wall is constructed on the cavity principle.

All chimneys should be carried at least 3 feet above the roof.

When constructing jambs to fireplace openings it should be remembered that splayed jambs give more heat into the room than square jambs.

A flue to prove most serviceable should be about one-twelfth of the size of the fireplace opening. As a general rule the smaller the flue and the greater the height, the more rapid will be the draught.

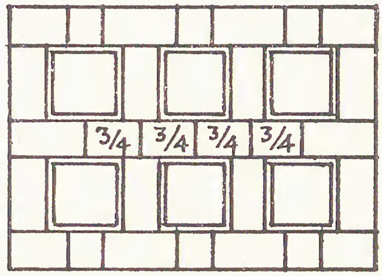
Agricultural drainpipes are sometimes let into the side of a flue pointing upwards in order to afford additional up draught, and in this may be found a remedy for a smoky fireplace.

Chimneys which are built in rubble and cut stone should have the flues formed in brickwork.

To increase the size of a chimney stack in order to accommodate additional flues from below, the area of the stack must be increased by corbelling out within the floor depth.

A cantilever corbel in stone will supply the extra width where the addition is too great to be formed in brickwork.

Chimney Shafts for Furnaces.—The thickness of the walls at the top of chimney shafts, and for a distance down of 20 feet, should not be less than 14 inches in shafts of 100 feet or more in height, and this thickness must be increased 4½ inches for every 20 feet downwards. A shaft should taper from its base inwards to the top at an angle of not less than 2½ inches in every 10 feet. Shafts should not be built in cement but in lime mortar, and a satisfactory bond is one course of headers and four courses of stretchers. Where the shafts are to be subjected internally to great heat they should have a lining of firebrick carried to a height of at least 25 feet.



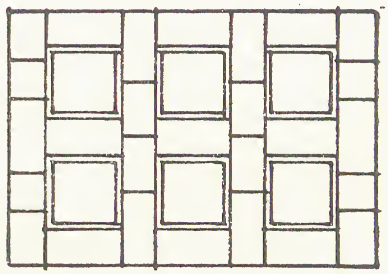


Fig. 115.—Six-flue chimney stack with $4\frac{1}{2}$-inch walls in Flemish bond.

FAULTS IN FLUES—CAUSES AND REMEDIES

The main cause of trouble with smoky fires is faulty construction, and with the revival of the open fire, one aspect of this has come to the fore. The opening of the fireplace itself having been enlarged to dimensions existing in earlier times, the same reduced flue, suitable for use with a small interior fitment, is required to accommodate a cubic content of air and smoke which in the past was served by a considerably larger flue. The point is overlooked that, in increasing the size of the fireplace opening, the flue should also be increased.

The most economical remedy is to decrease the size of the open fireplace, or that portion of it with which the flue is concerned, by constructing a copper hood diminishing upwards to a metal flue leading into the brickwork flue.

Another frequent cause of a smoky fire, due mainly to the necessity for saving expense, is the construction of chimneys that are too short. A smaller grate with a blower will increase the draught, but a more satisfactory remedy is to increase the height of the chimney.

The opposite of the first-mentioned cause, namely, the size of the flue being too large for a small fireplace fitment, is also a cause of a smoky fire, the cubic content of cold air contained in the flue being too heavy for the amount of heated air provided by the fire to shift readily, the consequence being a smoky fire. The obvious remedy is to reduce the size of the flue.

In the same class as the last may be considered the space left behind the arch of the fire by the gathering in being started too high up, thus giving rise to pockets in which cold air collects. These cold-air pockets, when a fire is lit, become eddies, giving a circular motion to the air contained in them, with the result that the smoke eventually finds its way down into the room. The remedy again is to reduce the size of these air pockets either by rebuilding the gathering in, or to build in a metal or fireclay flue, turning arches to support it.

Chimneys are frequently caused to smoke by conditions external to the building. These are nearly always conditions which cause the prevalent wind to be deflected downwards. It may be that the chimney is terminated below the ridge of a roof close by, or it may be that there are overhanging trees or high ground in the immediate neighbourhood. The remedy for these conditions is the same—that is, to increase the up draught by building one of the down-draught-preventing caps or erecting a special down-draught-preventing cowl.

A further remedy for the last-mentioned cause of a smoky fire is to fix ventilated openings in the walls of the hit-and-miss pattern, so that they can be opened or closed as required, in accordance with the direction of the wind. The effect of wind upon a building is to create a condition of high pressure on that side facing the direction from which the wind is blowing. And on the opposite side of the house a condition of low pressure is created. This gives rise to a current of air from the high-pressure area to the low pressure, as the chimney affords a suitable opening down which this current may pass. Consequently, if ventilators be built in opposite walls of the room from which a fire smokes from this cause, another channel will be found for this adjusting current of air, and the chimney allowed to perform its proper functions.

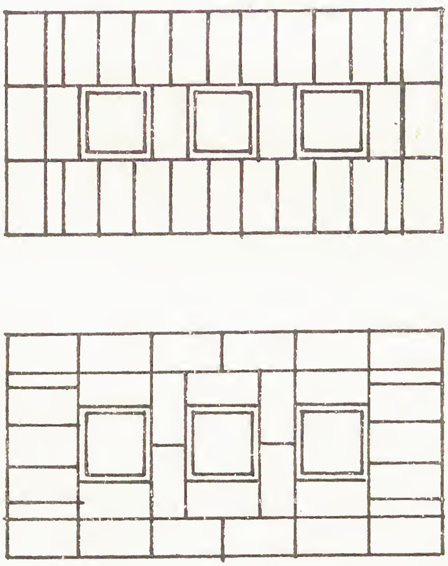


Fig. 116.—Chimney stack with 9-inch outer walls in English bond.

To use in conjunction with these ventilated grids, further air gratings may be fixed in the front of a raised hearth communicating by ducts under the hearth to the underside of the fireplace. If these are also fitted with hit-and-miss grids, the draught under the fire may be regulated as desired.

SETTING STOVES AND RANGES

Where the rough opening left for the fireplace is required to be filled in with a mantel register the brickwork will require to be built up, when the existing rough work should be cut away for the filling to be bonded into it. The fitment should be filled in behind with a backing of brickwork, and the opening at the top of the fitment should be built up to the flue in as easy bends as possible, and in such a manner that no horizontal surfaces are left on which soot will collect. The fitment must be firmly and solidly set upon its base, and any lugs that there may be built firmly into the brickwork and set in cement.

Kitchen ranges and coppers must be set either in cement mortar or in fireclay mortar composed of 3 parts of fireclay to 1 part of plaster of Paris. The actual operations in connection with setting a kitchen range naturally depend on the nature of the range. It is customary now to use very much lighter kitchen ranges than in the past. The old-fashioned range required the formation of a brick flue from the dampers under the oven behind the range leading to the main flue. The space behind the arch and below the gathering in of the flues is closed by a covering-in plate which is generally provided with a cleaning door.

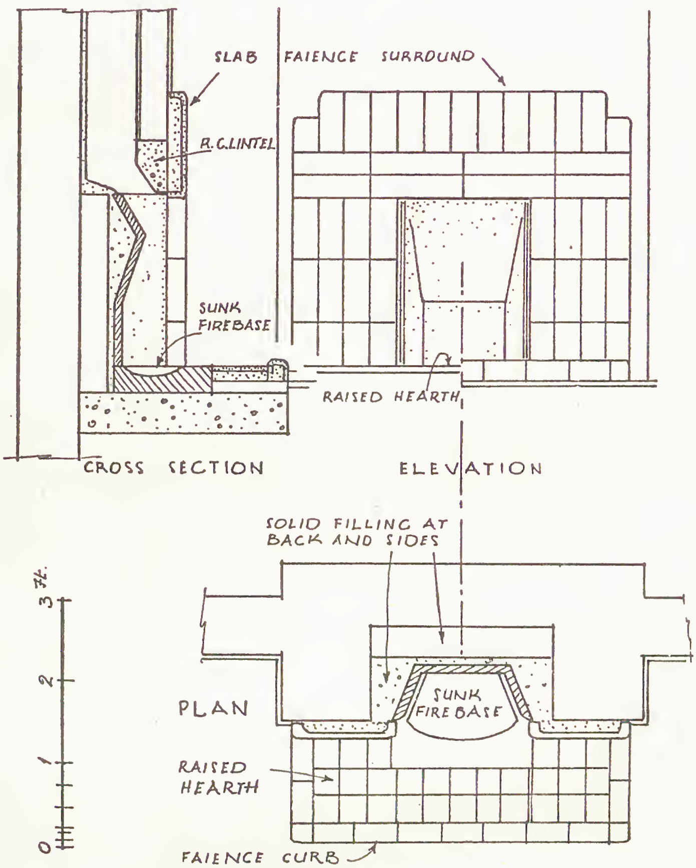


Fig. 117.—Fireplace with slab surround and sunk fire base.

Coppers.—Though the portable metal copper is generally used in preference to the old-fashioned built-in copper, yet it is still required of the bricklayer that he should understand the special construction required.

The Construction of the Flue.—The object required of the flue is that it should run round the surface of the copper pan in order that the water may be readily heated. The flue should be thoroughly parged; and whereas a corner is generally chosen for the copper, and the flue is led off into one of the walls forming the corner, care must be exercised in seeing that the junction between the flue round the copper and the flue in the wall is not constructed at such an angle as to give an unsatisfactory draught or to afford lodging places for soot. The fire front is fitted with a door and frame of wrought iron, and the bottom of the furnace is formed of bars raised from the ground over a rectangular opening in order to afford additional draught and at the same time to bring the fire close to the underside of the copper. The flue is commenced at the back of the furnace running round the outside of the pan, gradually rising from the fire pit until the height of the flue in the wall is reached. Into the flue in the wall there should be built a damper door and frame about a foot above the copper. Any filling in behind the facing bricks should be done in concrete, and the sides, back, and top of the furnace should be constructed in fireclay brick set in fireclay mortar or 3 parts fireclay to 1 of plaster of Paris. The flue in the copper itself should also be built of firebrick set in fireclay mortar.

For ordinary-sized coppers of about 20 gallons there will not require to be any footings, the walls resting on the concrete of the floor. A 20-gallon copper pan is 1 foot 6 inches deep and 1 foot 9 inches in diameter. The height from the floor to the top of the brickwork should be 3 feet. The firebox is 6 inches high by 9 inches wide. On the top of the brickwork there should be a rendering of sand and cement, with a finished surface sloped inwards towards the copper for drainage. Soot doors must be arranged in the flue both at the top and bottom, and there should be a space of 7 inches for an ash hole.

Hot-water Boilers.—Boilers for hot-water heating require special bases and foundation walls, which must be given spread footings and concrete foundations as to other walls. The flues must be lined with fireclay bricks set in fireclay mortar of as narrow dimensions as possible.

Note.—The exact dimensions of these flues required for any particular fittings should be ascertained from the makers.

A further point worthy of noting is that any very large boilers must be lowered into a basement before the floor above is built.

Ranges in hotels and in large buildings used for institutions are flat-topped, and stand in the centre of the kitchen, and in most modern work are heated by gas. The flues are formed of metal, and in many instances are of a type known as *Descending Flues.*

Hard-coal Ranges, for slow combustion, are to be obtained which stand on a York stone hearth and are connected by a metal flue to the chimney. The fireplace opening must be closed with either a metal plate or be bricked up and plastered over.

BY-LAWS

Though the contractor may receive detail setting out of fireplaces, he will be well advised to consult the local building by-laws before starting the actual work, as there are perhaps more bye-laws with regard to fireplaces and flues than any other detail of a building. The obvious reason is for the prevention of fire.

The following is from " Model By-laws " issued by the Ministry of Housing and Local Government :

CHIMNEYS, FLUES AND HEARTHS

" **53.** ***Materials.***—Every chimney, the back and jambs of every fireplace opening, and every hearth shall be constructed of suitable incombustible materials so put together and arranged as to prevent the ignition of any part of the building.

"**54.** ***Exceptions.***—By-laws 55 to 67 shall not apply

"(*a*) to any chimney for the furnace of a steam boiler, engine, brewery, distillery or manufacture;

"(*b*) to any chimney shaft to which by-laws 70 to 73 apply;

"(*c*) to any chimney which is so constructed as not to be capable of use except in connection with a fire or stove which burns gas only; or

"(*d*) to any chimney which does not form part of the structure of a building.

"**55.** ***Hearths.***—(1) Every fireplace opening shall have a hearth which shall

"(*a*) extend under and in front of the opening;

"(*b*) project at least 16 inches from the chimney breast and extend at each side at least 6 inches beyond the opening;

"(*c*) be not less than 6 inches thick; and

"(*d*) where the hearth is in contact with a floor of combustible material be so laid that the upper surface of the portion in front of the fireplace opening is not lower than the floor.

"(2) No timber or other combustible material other than timber fillets supporting a concrete hearth shall be placed under any hearth constructed in connection with a fireplace opening within a distance of 10 inches, measured vertically from any point on the surface of the hearth.

"(3) Nothing in this by-law shall prevent the construction of a pit as an ash container for a fire, if the pit is constructed of brick or concrete not less than 2 inches thick, rests solidly upon the ground and has no combustible material nearer to the inner surface of any of its sides than

"(*a*) 3 inches where that surface is distant not less than 12 inches measured horizontally in any direction from the fire; or

"(*b*) 10 inches where that surface is less distant than as aforesaid.

"**56.** ***Jambs.***—The jamb on each side of a fireplace opening shall be not less than 8½ inches wide.

"**57.** ***Lintels, etc.***—A sufficient arch or lintel of brick, stone or other hard and suitable incombustible material, or a sufficient bar of steel, wrought iron or other not less suitable metal, shall be built over the fireplace opening to support the chimney breast.

"**58.** ***Thickness of Back of Openings.***—(1) Where a fireplace opening is in an external wall, the back of the opening shall be not less than 4 inches thick.

"(2) Where two fireplace openings are built on the opposite sides of a wall, other than a wall separating buildings, any part of the back common to the two openings shall be not less than 4 inches thick.

" (3) The back of every other fireplace opening shall be not less than $8\frac{1}{2}$ inches thick.

" (4) The thickness required by this by-law shall extend to a height not less than 2 feet 6 inches above the level of the hearth where the opening is constructed to receive an open fire, and in any other case to a height not less than 12 inches above the fireplace opening.

" **59.** ***Damp-proof Courses, etc.***—A chimney which is built against or forms part of a wall and extends to or below the surface of the ground adjoining the wall shall be deemed to be part of that wall for the purposes of by-laws 29 and 30.

" **60.** ***Thickness of Chimneys.***—(1) A chimney shall have a minimum thickness of solid material of 4 inches if constructed of bricks, blocks or concrete cast *in situ*, and of 6 inches if constructed of stone;

" Provided that where the chimney passes through a roof which is covered with thatch or other combustible material, the thickness shall be increased to not less than $8\frac{1}{2}$ inches for a distance of not less than 4 inches above and below that material.

" (2) Where a chimney is in a wall separating buildings and is not back-to-back with another chimney, the material at the back of that part of the chimney which is below the roof shall be not less than $8\frac{1}{2}$ inches thick.

" (3) Where the course of a flue makes with the horizontal an angle of less than 45 degrees, the upper side of that part of the chimney shall be not less than $8\frac{1}{2}$ inches thick.

" **61.** ***Lining of Chimneys.***—Every chimney shall be properly lined, pargeted or otherwise suitably protected.

" **62.** ***Rendering of Outside of Chimneys, etc.***—Where part of a chimney constructed of bricks, stone or blocks, other than flue blocks having no vertical joints, is less than $8\frac{1}{2}$ inches thick, the surface of that part if within a building shall be rendered or otherwise suitably protected.

" **63.** ***Timber, etc., in or Near Chimneys.***—(1) No timber or other combustible material shall be placed in a wall or chimney breast within a distance of 9 inches of a flue or fireplace opening or of any opening into a flue or fireplace opening: Provided that a wooden plug may be placed not less than 6 inches from the flue or opening.

" (2) No timber or other combustible material, being part of the structure, shall be nearer to the face of any rendering required by the last preceding by-law than $1\frac{1}{2}$ inches.

" **64.** ***Metal Fastenings.***—No metal fastening which is in contact with any combustible material shall be placed within 2 inches of any fireplace opening or flue.

" **65.** ***Chimneys to be Weatherproof.***—The chimneys of every domestic building of every public building and of every building of the warehouse class in which persons are intended to be habitually employed in manufacture, trade or business, shall adequately resist the penetration of rain and snow into the building.

" **66.** ***Minimum Height of Chimneys.***—(1) Every chimney shall extend to such a height above the adjoining roof, as to comply with the following requirements of this by-law.

" (2) Where a chimney is carried up through the ridge of a roof which has a slope on both sides of the ridge of not less than 10 degrees with the horizontal, the top of the chimney shall be not less than 2 feet above the ridge, and in any other case the top of the chimney shall be not less than 3 feet above the roof, measured from the highest point in the line of junction with the roof.

" **67.** ***Width of Chimneys.***—The least width of a chimney or of a group of chimneys bonded together measured horizontally at right angles to its greatest horizontal dimension shall be not less than one-sixth of the height of the chimney or group of chimneys above the highest point in the line of junction with the roof, unless the chimney or group of chimneys is otherwise made secure.

" **68.** ***Flues communicating with Habitable Rooms.***—A flue which communicates with a room intended for human habitation shall not communicate with any other room :

" Provided that nothing in this by-law shall prohibit the use of a common flue in connection with a back-to-back grate."

CHAPTER 4

TERRA-COTTA. WALL AND PARTITION BLOCKS

In addition to ordinary brick and stone blocks, wall units of other materials are available. These are: terra-cotta which is used in the manufacture of special blocks designed for the individual building, and of certain standard walling blocks; hollow clay blocks for walls and partitions; cement concrete hollow and solid blocks; light-weight concrete blocks; glazed fireclay blocks; plaster blocks or slabs.

These block units are often used in a composite form of wall construction, either as a facing or backing.

TERRA-COTTA

Terra-cotta consists of blocks of burnt clay. Plain, unglazed terra-cotta is produced in a range of colours including buff, grey, biscuit and red, with plain or dragged surface. It is used as a facing for outside walls, and also for partition blocks. The surface is hard, dense and durable.

Vitreous glazed terra-cotta has a smooth, glazed surface, and is produced in stone, brown, buff, light grey and mottled grey colours. The surface is almost waterproof, easily cleaned and durable.

Fully glazed terra-cotta has a thick full glaze which is impervious, easily cleaned and durable. It is produced in white, cream, brown, green, blue, old gold, blue mottled and tortoiseshell colours.

Terra-cotta blocks are usually made hollow, and are open at the back or top. Large blocks have interior webs to stiffen them. The blocks are usually filled with weak concrete of a 1 cement : 1 sand : 8 fine broken brick mix, the concrete being lightly tamped into the block. A strong cement concrete must not be used, owing to the possibility of expansion disrupting the block. If old bricks are broken down for aggregate, old mortar should be removed, as this may contain particles of free lime.

Terra-cotta, being a burnt clay product, is liable to distortion in burning. It shrinks when it is burnt, and for this reason a shrinkage scale is used in taking dimensions from drawings, thus allowing a little extra on the dimensions when making the clay blocks.

Designing.—Although large blocks up to 3 or 4 cubic feet can be made, it is usual to make the blocks much smaller. Courses 1 foot to 1 foot 6 inches thick are commonly adopted. This reduces distortion and makes for ease of handling.

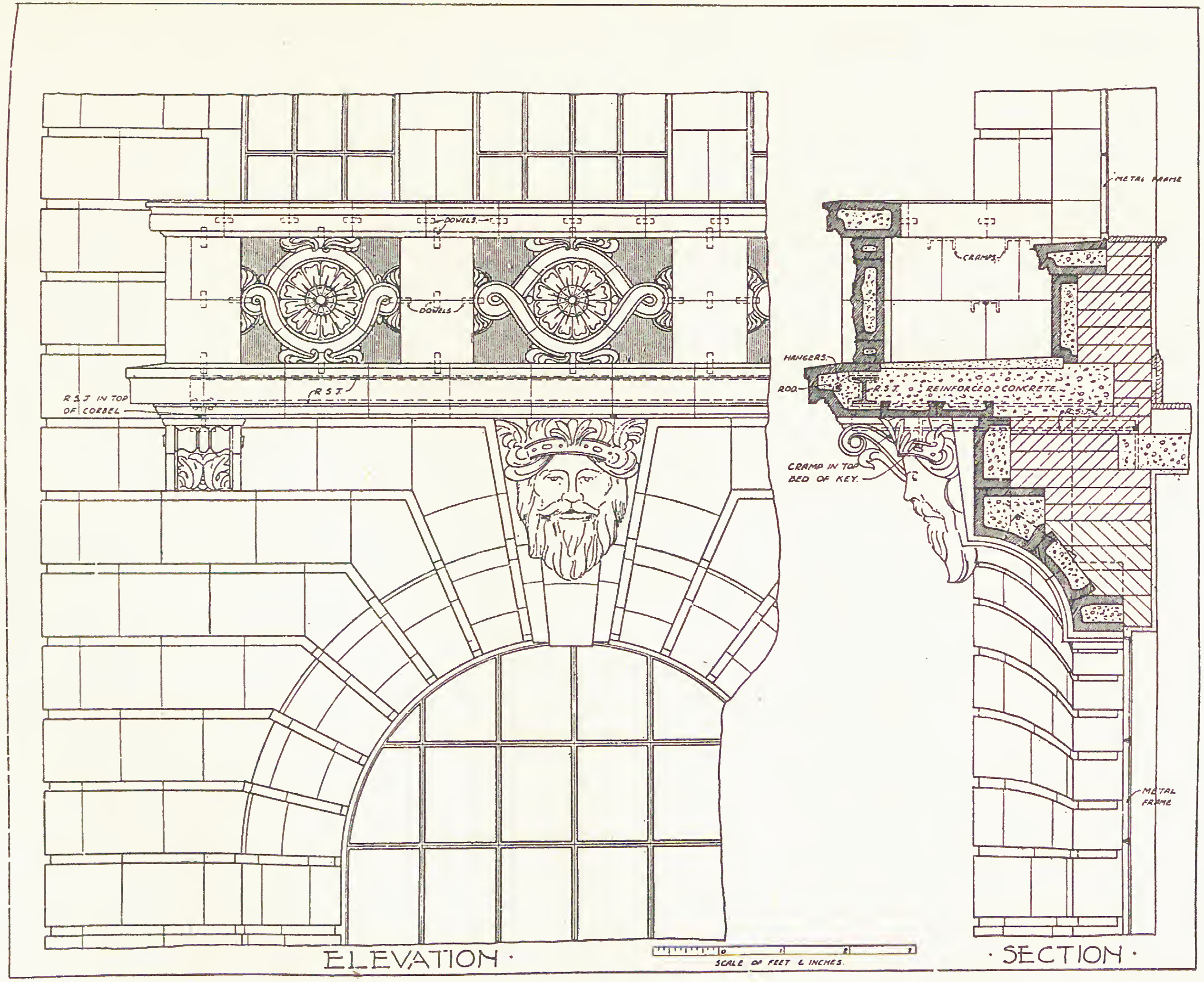


Fig. 118.—Detail of arch and balcony in terra-cotta.

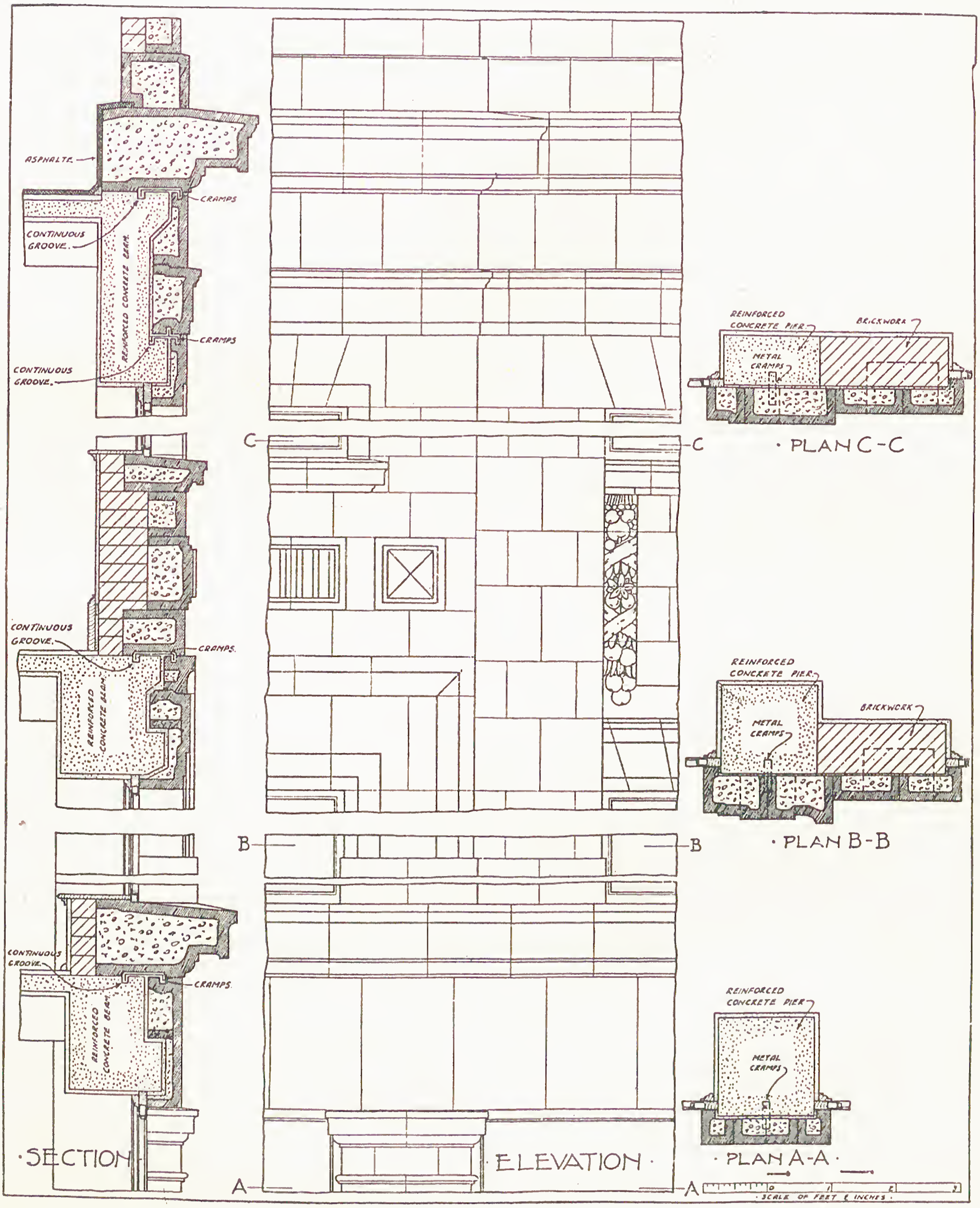


Fig. 119.—Terra-cotta facing with brick backing

Terra-cotta cannot be cut, so cramp holes, pipe holes, etc., must be moulded in the clay. The cost largely depends upon the amount of repetition—a large number of plain blocks of similar size is naturally much cheaper than a variety of sizes. A large number of different ornamental details greatly increases the cost.

Jointing must be arranged to suit the nature of the material, and is best left to the manufacturer's designers. They arrange the jointing to enable blocks to be produced without much distortion as well as to suit the wall construction. It is usual for the architect to supply the manufacturer with a set of drawings, including large-scale sections through mouldings. The rise of the courses of brick backing (where brick is used) is also given, so that the manufacturer can design the blocks to bond in with the brickwork. In supplying these particulars, care must be taken to include correct dimensions for wall lengths, positions of doors and windows, and pipe holes. Where the building is framed in steel or reinforced concrete, the engineer's drawings must also be supplied of those portions of the framing which affect the terra-cotta.

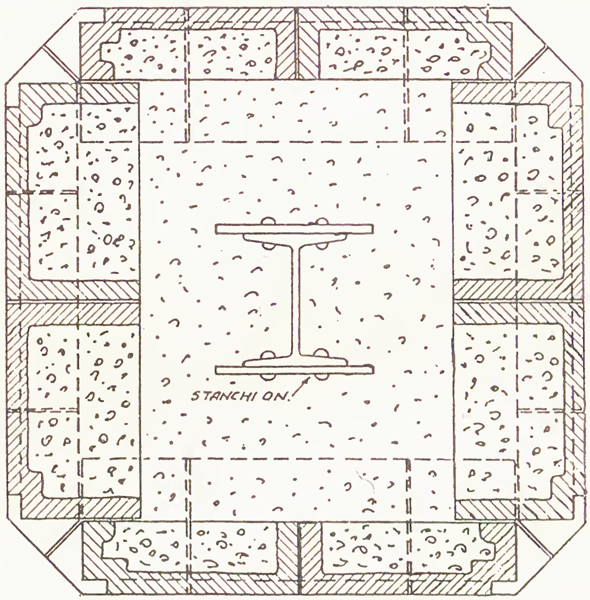


Fig. 120.—Plan of steel column with terra-cotta facing.

As the manufacturer must have time to prepare detail drawings, to make moulds, and then to cast the blocks and allow them to dry, the order for the terra-cotta must be given well in advance of the required delivery date. This varies with the amount of ornamental detail and the size and variety of the blocks. A small plain block takes only a few days to dry, but a large block of irregular shape may take a month. Then the blocks have to be burnt. If the drying period is cut down, the blocks are liable to distort or to develop defects.

Fixing.—Special drawings are supplied by the manufacturer for this purpose. These drawings are made to a scale of 1 inch to 1 foot, and all joints and blocks are shown. Each block is numbered on the drawing, and the actual block is stamped with the same number. By this means the position of every block is clearly indicated to the foreman on the site.

Great care should be taken not to damage the blocks in unloading and handling. On delivery, the blocks should be checked with the invoice, and the blocks delivered ticked in red pencil on the drawing. Truck-loads should be kept separate. By doing this, individual blocks can easily be traced from the appropriate invoice. If any blocks are missing or found damaged, the manufacturer should immediately be notified.

Cleaning.—While fixing, care should be taken to keep the work as clean as possible. Mortar droppings and stains should be cleaned off before they set. Before moving away from recently set work, it should be washed over with a distemper brush dipped in clean water and then rubbed dry with a clean cloth.

For large work, the joints should be raked out when the mortar has set sufficiently to enable this to be done without disturbing the work, and the pointing and cleaning left until the scaffolding is removed. The final cleaning down can then be done with a stiff brush and clean water. Any mortar stains that have set hard can be removed with a dilute solution of spirits of salts—about 10 parts water to 1 part spirits of salts, the solution being mixed in an earthenware or wooden vessel. But this solution is injurious to the mortar joints, so should be kept off the joints, and washed off the block after removing the stain.

Spirits of salts should not be used for cleaning glazed terra-cotta, or the glaze may be injured. Care should be taken not to allow any mortar to set on the glaze. Soap and water can be used for the final cleaning down, washing off the soap and rubbing dry to finish.

Properly burnt terra-cotta is an exceptionally durable material. In Italy terra-cotta work is still in excellent condition after several centuries of weathering. The blocks weather evenly, so that patchiness is avoided. Blocks under cornices and other projections become coated with soot in a town atmosphere, but the more exposed surfaces are washed by the rain.

Old dirty terra-cotta should be cleaned by using clean water and a scrubbing brush, or by steam cleaning. Chemicals should not be used.

Coloured glazed terra-cotta, usually called faience, is the best and most durable means of providing bright colour in the elevations of buildings. The colours do not deteriorate and the glaze of the best makes may be relied upon not to craze. Periodical cleaning will keep the colour bright.

Faience Slabs.—Slabs of fully glazed terra-cotta are extensively used for facing the walls of modern buildings. The slabs are about 1 inch thick and are usually made 2 × 1 foot. They are secured to the brick or concrete wall by metal cramps, and the slab edges have slots for receiving the cranked ends of the cramps. The slabs are backed against the brickwork or concrete with ½-inch mortar.

Fig. 121 shows some of the patterns which are used for the slab facing. It will be seen that the older principles of bonding are discarded in this work. It is not considered to be necessary, as the slabs are secured by the metal cramps.

Specially moulded slabs forming recesses for neon tubes are shown in Fig. 121. When lit up at night these form bands of brilliant coloured light. The faience slabs are made in several colours, and ornamental features can be introduced. These slabs are largely used for facing

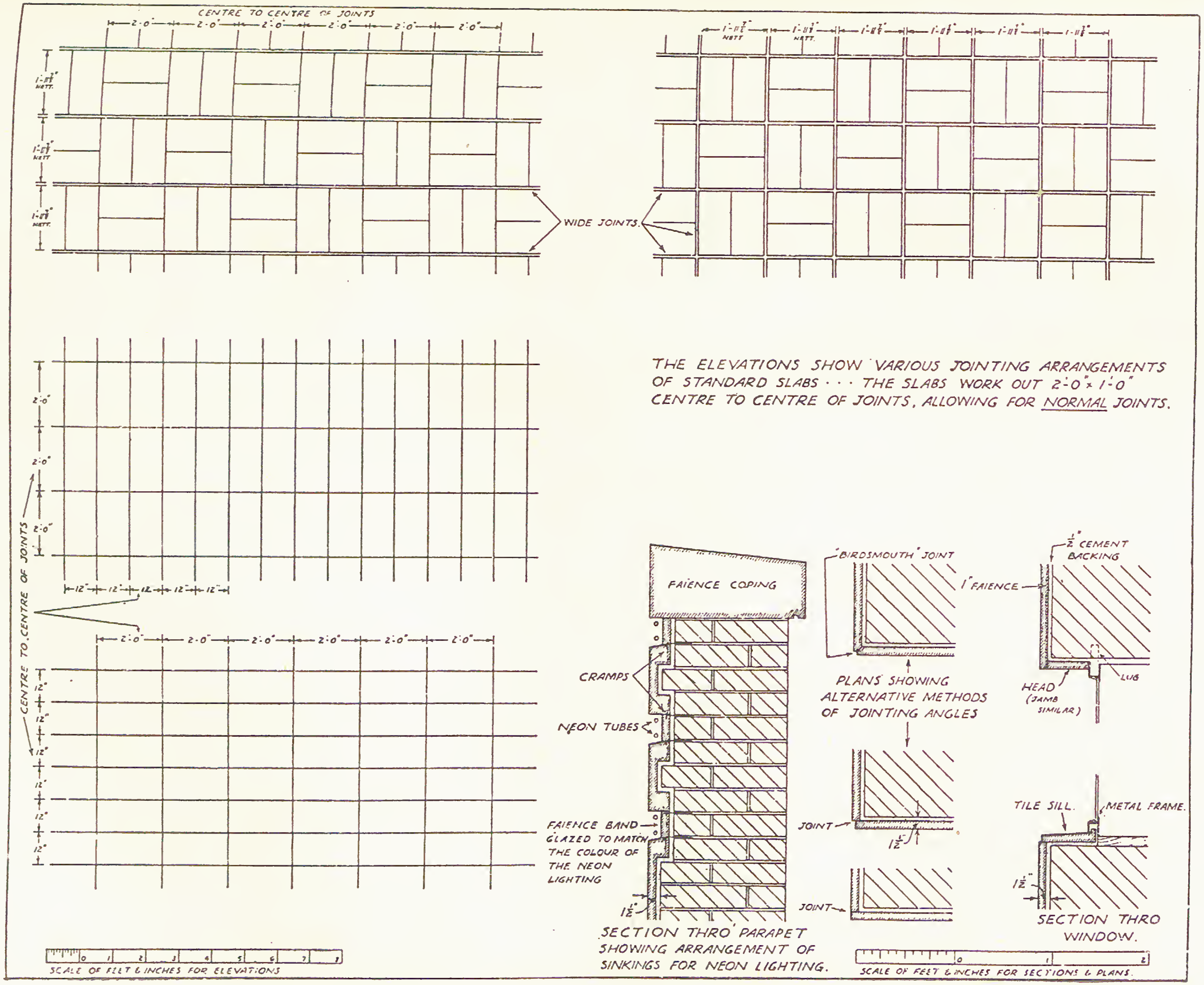


Fig. 121.—Faience slabs for wall facing.

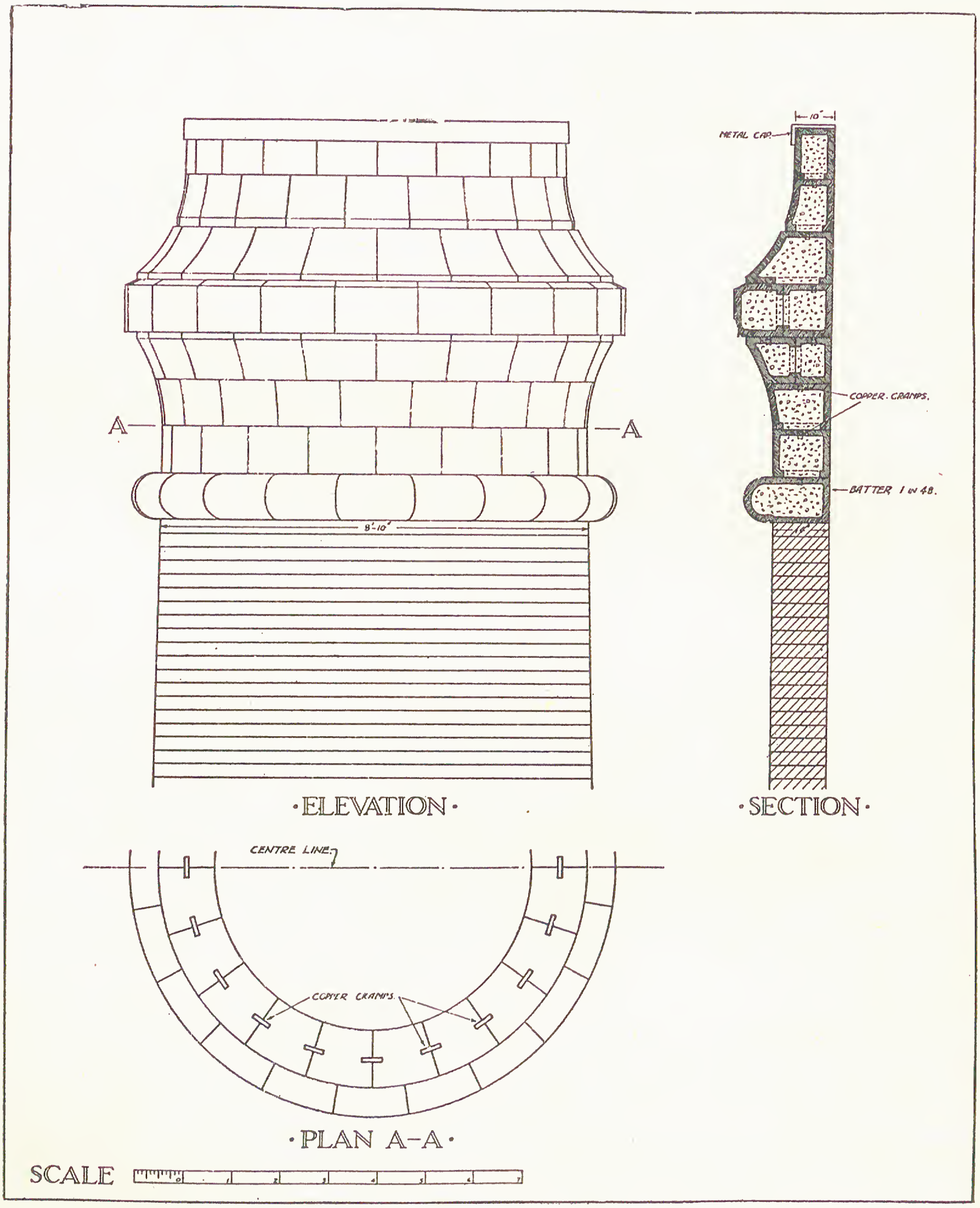


Fig. 122.—Terra-cotta cap to tall chimney stack.

modern cinemas, public houses, shop and office buildings.

HOLLOW BLOCKS

Hollow blocks are made of brick, terra-cotta, diatomaceous earth and concrete. They are, of course, much lighter than solid blocks of the same size, and this is a considerable advantage in transport, handling, laying, and in keeping the dead load of the building to a minimum. The importance of this last point particularly applies to tall buildings. The greater the dead load of walls, floors and partitions, the heavier must be the steel or reinforced concrete framework and the foundations.

Hollow blocks are also useful for the rapid construction of light buildings.

Materials.—These are: gault clay, kiln burnt; extruded terra-cotta; diatomaceous earth.

The clay and

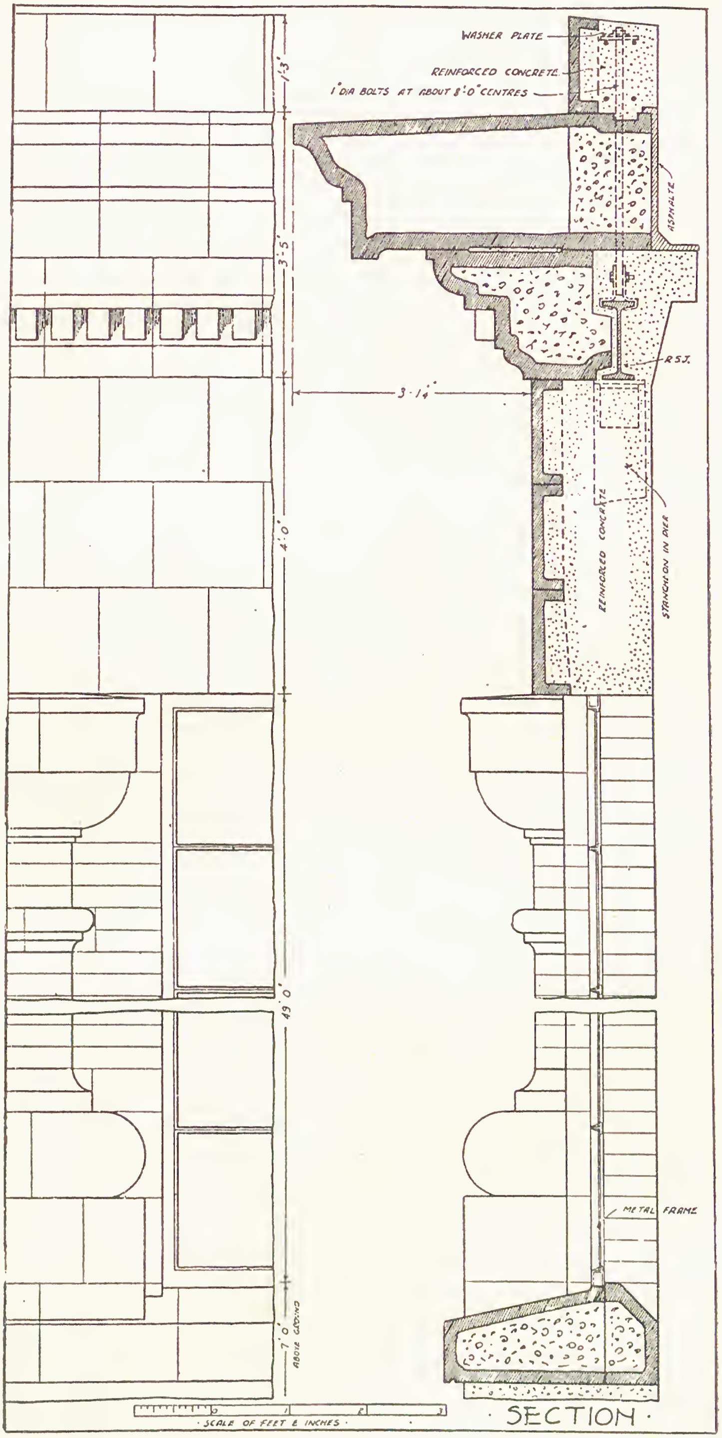


Fig. 123.—Cornice, parapet, window head and sill in terra-cotta

terra-cotta blocks are produced by extrusion, a process which results in regular shapes without distortion. The blocks are hard and well burnt. Diatomaceous earth, of which several proprietary blocks are made, is a grey siliceous earth which has high sound and thermal insulation, and high value for fire resistance.

Types.—Hollow blocks are divided into cells, as shown in Fig. 125. Some have two and some three cells. The blocks are made with a plain surface for walls and partitions which are not to be plastered, and with a keyed surface for plastering. The key consists of horizontal parallel grooves. Some blocks have deep grooves for taking electric wiring conduit.

The strength of hollow blocks of the type described is adequate for ordinary loads. Crushing strength varies from about 350 lb. per sq. in. for the lighter partition blocks to about 1,000 lb. per sq. in. for the heavier blocks suitable for load-bearing walls.

Stop end, half blocks and other specials are made so that all the problems of bonding can be met without cutting.

Pre-cast concrete blocks are described in Chapter 11. There are various proprietary types, but the standard two-cell block, 18 × 9 × 9 inches, is the most useful for outside walling. The cells form continuous vertical cavities. To carry heavy point loads these cells can be filled with concrete, and also reinforced with vertical rods.

Sizes.—The sizes of hollow blocks are in most cases 12 × 9 inches, with thicknesses of $1\frac{1}{2}$ inches, 2 inches, 3 inches, 4 inches, $4\frac{1}{2}$ inches and 6 inches. Cellular bricks are made in standard brick size.

The 6-inch blocks can be used for outside walls, and are of adequate strength for bearing the normal loads met with in two-floor houses. Two skins of $4\frac{1}{2}$ inches can be used where it is desired to have a 9-inch-thick wall. For light partitions the 2-inch and 3-inch blocks are normally used.

Thermal and sound insulation for hollow blocks is usually at least as good as for solid brickwork of the same overall thickness.

Absorption of water varies with the material and thickness, but 6-inch blocks are sufficiently watertight for fairly sheltered outside walls. For exposed positions, rendering the exterior with a cement-sand mix, preferably waterproofed, will ensure watertightness.

Composite Walling.—There are certain advantages to be gained by using one material for facing and another for backing in walls. A durable weather-tight material can be used on the outside with a weaker and more porous material inside.

Thus, outside walls may consist of a $4\frac{1}{2}$-inch solid brick outer skin bonded to a hollow block backing. Blocks of pumice concrete or plaster may be used for the backing for small buildings where the loads to be supported are light.

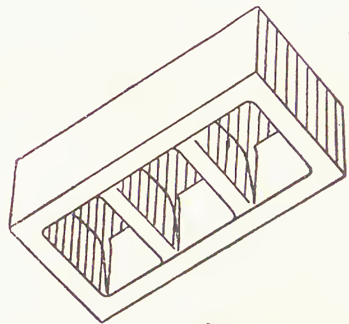
The composite use of stone as a facing and brick as a backing has already been described in Chapter 12. Solid bricks or hollow blocks can be used in conjunction with poured concrete. The brick or block facing forms a permanent shuttering for the exterior. Metal ties should be embedded in the concrete and the brick or block beds. Alternatively every few courses can be bonded into the concrete.

Six examples of composite walling are illustrated in Fig. 126. Section A has $4\frac{1}{2}$-inch brickwork as a facing skin and 4-inch cement concrete as a backing. Metal ties are embedded in the concrete and into every fifth bed joint of the brickwork. Alternatively, header courses of bricks might be used to bond through the concrete. It will be understood that the brickwork acts as permanent shuttering to hold the poured concrete. If a suitable water-resisting sheeting is used for the inside lining, and is temporarily supported by timber rails and struts, no temporary close-boarded shuttering is required. This is a useful form of walling where bricks or bricklayers are scarce. The cost would be about the same as for solid brickwork.

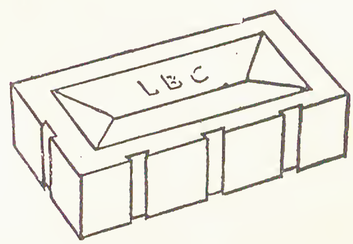
Section B is another composite wall with a $4\frac{1}{2}$-inch brick facing skin, the backing in this case being 3-inch hollow blocks. The two skins are bonded together with metal ties. The use of hollow blocks for the backing reduces the dead load of the wall.

Section C is a brick wall designed for minimum weight and cost. The $4\frac{1}{2}$-inch brickwork in cement mortar has horizontal reinforcement every fourth course. The thermal and sound insulation is improved by plastering on expanded metal secured to $2 \times 1\frac{1}{2}$-inch battens fixed to wall plugs.

Section D illustrates a reinforced concrete wall with natural or pre-cast stone facing slabs. By providing temporary support for the slabs and using a water-resisting sheeting for the interior lining, temporarily supported, both the outer and inner facing could form permanent shuttering, thus saving temporary close-boarded shuttering.



A



B

Fig. 124.—A. Cellular brick. B. Brick with keyed face.

Section E is a $4\frac{1}{2}$-inch brick wall with light-weight cellular concrete blocks as backing. The latter is added to give a good standard of thermal and sound insulation, the brick skin being the load-bearing portion. This walling is suitable for small light buildings or panel filling in a framed building.

Section F illustrates a wall of 6-inch hollow blocks with 2-inch natural stone, or pre-cast concrete slab facing secured to the blocks with metal ties or cramps.

In designing a composite wall the following factors must be considered :

(1) The outer wall or facing must be sufficiently weather-resistant and durable.

(2) Consideration must be given to loading (load bearing or non-load bearing).

(3) The outer skin may be weather-resisting and load bearing, while the inner skin is a light-weight material added for thermal and sound insulation.

(4) The advantages required over an ordinary brick wall should be considered. For example, light weight, increased speed of construction, economy of materials which are scarce or costly, saving of skilled labour which may be scarce, saving in cost.

Regarding cost, it is not easy to design an alternative walling which has the same strength, weather resistance and insulating properties of ordinary brickwork. But in many cases an alternative walling is preferable owing to local circumstances.

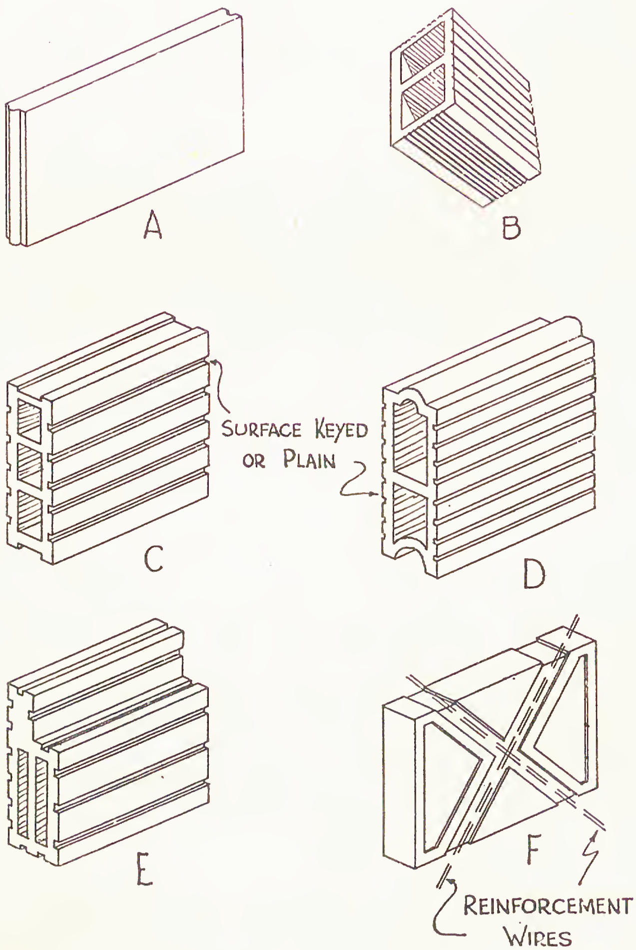


Fig. 125.—A. Plaster slab. B. Hollow clay block. C, D, E. Hollow blocks of clay or diatomaceous earth. F. Clay blocks with grooves for face reinforcement.

Glazed Partition Blocks.—These are glazed fireclay blocks, with white or coloured glaze finish one or both sides. One make is $12 \times 9 \times 2\frac{1}{2}$ inches, and another $9 \times 2\frac{7}{8} \times 2\frac{1}{2}$ inches. The blocks are tongued and grooved all round for extra security when laid.

The larger blocks, glazed both sides, are suitable for lavatory and other small partitions. The blocks glazed one side are used for facing to a brick or other backing. They can also be used as an inner leaf in cavity wall construction.

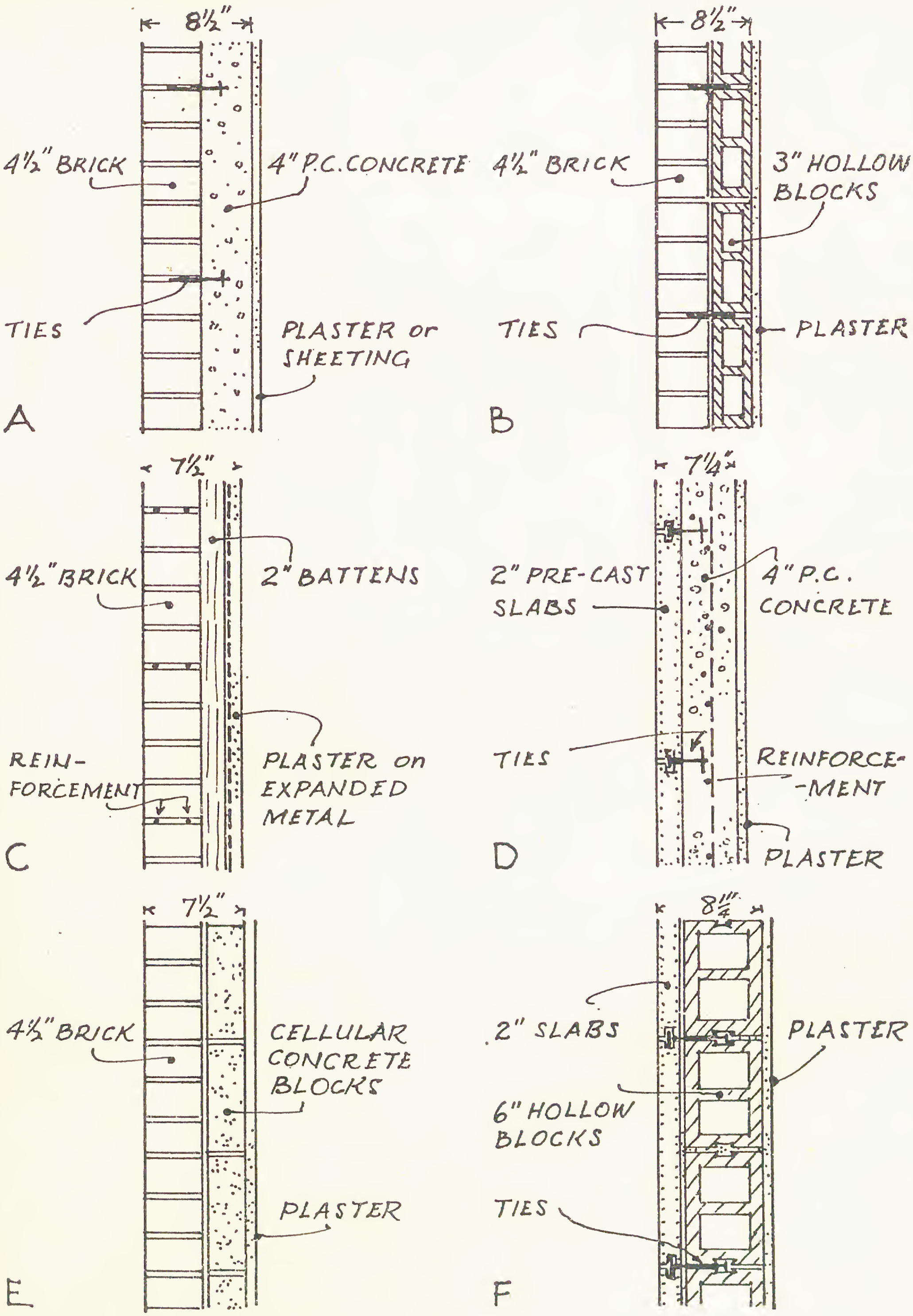


Fig. 126.—Composite wall constructions.

PLASTER BLOCKS

Plaster blocks are largely used for interior non-load bearing partitions. They are made from plasters of the calcium sulphate types which are hard and strong. The blocks are of light weight, easily handled and fixed, and, if necessary, can be sawn. They are suitable for non-load bearing partitions only, and must not be used to support ceiling joists or upper floors.

One of the best makes of plaster block is made from the anhydrite form of calcium sulphate which, unlike gypsum and similar forms of calcium sulphate, is highly resistant to intermittent water attack. The plaster is cast into precision moulds which ensure extreme accuracy of the cast blocks. The blocks are free from the harmful differential movements which are encountered with cement-bound blocks, and are not affected by comparatively large variations of humidity and temperature. The surface is smooth and true, and can be decorated or plastered.

Sizes.—24 × 12 inches with four thicknesses, 2 inches, 2½ inches, 3 inches and 4 inches. There is a slight plus and minus margin of size.

A typical plaster block weighs 57 lb. per cubic foot, or 40 cubic feet to 1 ton.

One ton of blocks will yield the following wall areas at 57 lb. per cubic foot (allowing for joints ⅜ inch thick):

2 inches thick	28 square yards
2½ ,, ,, ...	23 ,, ,,
3 ,, ,, ...	19 ,, ,,
4 ,, ,, ...	14 ,, ,,

The blocks may be laid in a cement mortar consisting of 1 part Portland cement to 4 parts clean sand by volume. Alternatively, a mortar may be made from the same plaster as used in the manufacture of the blocks, and supplied by the makers, consisting of 1 part plaster to 1 part clean sand by volume. The average thickness of joints should be ⅜ inch.

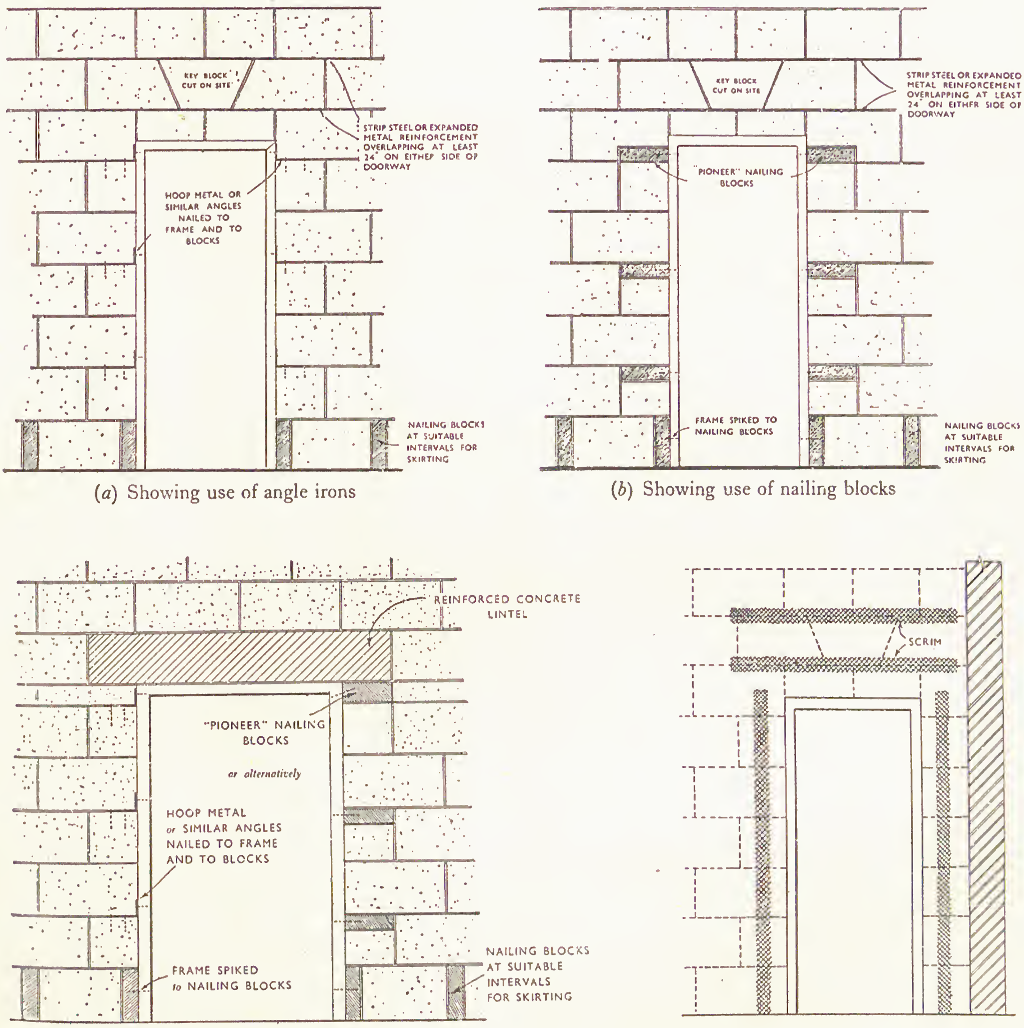
Plaster block partitions can be reinforced by embedding expanded metal, or other open-mesh reinforcement, or steel strip in every second horizontal joint. The thickness of block and reinforcement should be considered in relation to the size of the partition.

Construction.—Reinforcement is particularly necessary when a high degree of rigidity is required; when the vertical section of a wall or partition is suddenly changed, e.g. over doorways and over and under windows, and where excessive movement of the main structure is anticipated.

Where there is risk of thermal or shrinkage movements in walls, floors, roofs or framing, the partition must be "divorced" from the main structure, but at the same time it must not be deprived of lateral support around the edges. This relieves the partition of stresses caused by the movement or deflection of the structure, and also during the early life of the building prevents the passage of moisture from the main structure to the relatively dry plaster blocks. Divorcement of the partition from the structure reduces sound transmission whether air-borne or structure-borne.

The following methods of divorcing partitions are recommended :

(A) A fibre board strip set at the junction of the partition and the



(*a*) Showing use of angle irons

(*b*) Showing use of nailing blocks

(*c*) Showing reinforced concrete lintel

(*d*) Showing use of scrim treatment

Fig. 127.—Fixing door frames in plaster block partitions.

structure in the plaster supplied. The partition is then built against the strip, using a plastered joint.

Strips can also be placed between partition and floor and partition and ceiling. Felt may be used instead of fibre board.

(B) A fillet or batten fixed to the main structure around the opening to be occupied by the partition blocks. The partition is built on the fillet running across the floor, each alternate horizontal course being reinforced with a steel strip bent up at the ends and nailed to the vertical wood fillets. The joint between blocks and fillets must be left free from mortar. After plastering, a wood moulding is nailed to the wood fillets in order to cover the joints. Fibre board, felt, or cork strips can be laid across the floor instead of the wood fillet.

For fixing timber door frames in plaster block partitions steel strip angles or cramps are laid in the joints between the blocks and the door frame. Alternatively, special nailing blocks are laid horizontally round

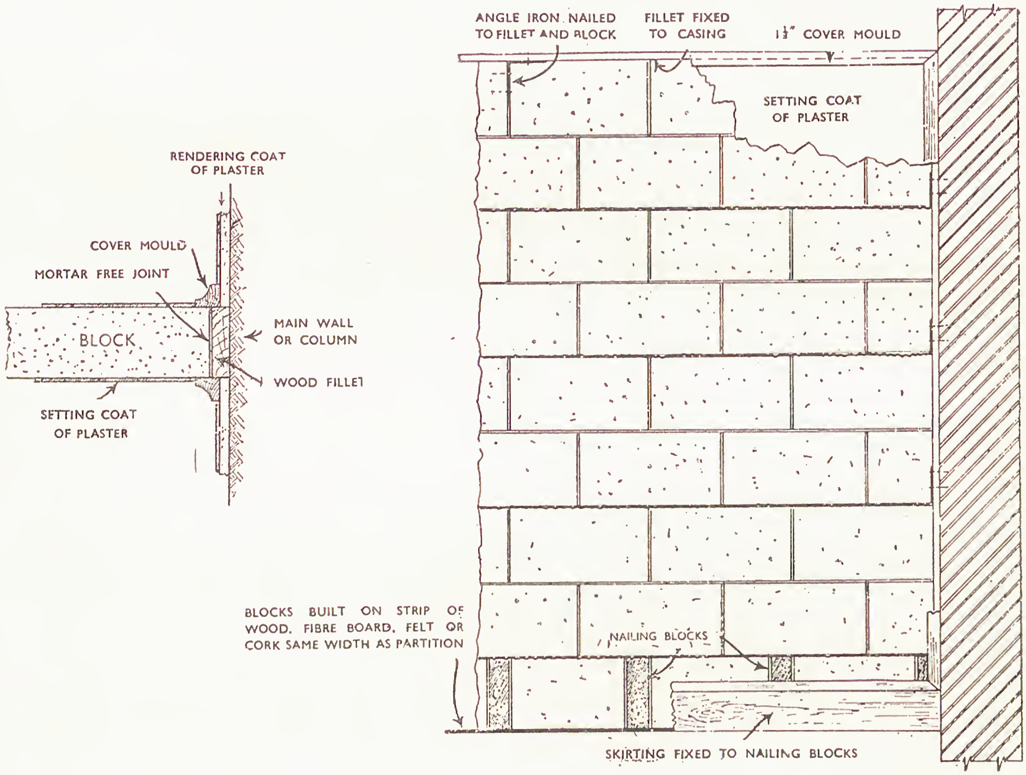


Fig. 128.—Fixing plaster blocks to walls and floors.

the door opening as the partition is built, and the door frame is then fixed as shown in Fig. 127 (*b*).

Where plaster blocks are laid against other materials, e.g. door frames, brick or concrete flues, lintels, wall plates, the blocks are laid flush with the other materials and a fine-mesh scrim fabric is laid over the joints and buttered in with the first application of the plaster finish.

Fittings can be fixed to plaster blocks partitions by using nailing blocks, patent fibre plugs, bolts with back plates grouted in a cement-sand mix, or expansion bolts. The block-maker's instructions should be consulted and the method of fixing carefully selected to suit the type and weight of fitting.

COB CONSTRUCTION

Cob Walling is a form of construction in which walls are formed by mixing clay and straw with sufficient water to make the clay readily workable. This method probably owes its origin to that early form of construction known as "wattle and daub," which consisted of clay mixed with chopped straw and chalk, worked well in between a timber frame skeleton. The whole was covered with a coat of plaster.

Cob is laid in courses of a foot or more in height at a time, starting from one corner of the building and running round until the starting-point is reached again, when it will be found to have set sufficiently for another course to be laid. Each course is consolidated by either being trodden into position or it is beaten with the back of a spade or a fork.

As a foundation to the cob a wall of brick, stone, or concrete is first built about 2 feet thick and 2 feet in height. The cob is then laid on this in diagonal layers and trodden down, so that the face of the cob work projects over the wall beneath $1\frac{1}{2}$ inches. In this method the openings are generally cut out after the whole of the walls have been erected to their total height. The walling is then generally left to dry out for several months before it is plastered, and the plaster is usually covered with a fine roughcast known as slap-dash.

In a more modern method the mixture of the wet clay and chopped straw is prepared in a pug mill. When mixed it is packed tightly into moulds $18 \times 12 \times 18$ inches. The moulds are then placed in a press and the cob is compressed to half its thickness under a pressure of about 2 tons. The blocks should dry out without cracking, and may be laid on the foundation wall, the first course being jointed in cement mortar. Above this the courses are jointed by wetting the blocks and pressing them into position.

Structural Improvements in cob walling may be effected by forming the quoins and abutments of openings in stone or brick, and lacing courses of these materials may be also introduced. The ground-floor walling should be about 2 feet thick and the upper walls 18 inches; but as the material is not suited to carry great weights, sounder construction will be to build either a bungalow or to form the upper storey in the roof with dormer windows.

The cob walling is fairly durable, but it requires protecting from the destructive effects of damp penetrating either from above or from below. The addition of some form of outer coat is recommended. This may be either that already suggested, *viz.* plaster or cement directly upon the cob surface, or it may consist of plaster or cement on metal lathing fixed to breeze blocks or creosoted wood bricks let into the cob walling.

PISÉ-DE-TERRE

This is a method of forming walls by ramming earth between board forms fixed upright. Almost any earths are suitable for this type of walling except very light earths or brick clays.

This method of construction was also made the subject-matter of an investigation undertaken by the Building Research Board, who went very fully into it and published a Report thereon, and to this the reader is referred for more detailed information than is contained in the following notes extracted therefrom.

The most Suitable Soils for pisé-de-terre are a strong earth mixed with gravel. Brick clay is likely to crack when used alone, and it is advised that carbonate of lime should be added to clay, which then forms what constitutes in fact a cement; and if stones are mixed with this as is advised, the result is practically a form of concrete. So regarded in this light, it is not unreasonable to expect a resultant material suitable for taking the light loads imposed upon the walls of low buildings not subject to any great shearing or overturning stresses.

Too much gravel or other forms of aggregate mixed in with the earth is likely to cause cracking, as there is not the bond afforded by cement as in concrete proper; and if the earth is used too wet, it will be found to cause cracking in the wall surfacing as it dries out, though at the time of erection it may appear to form a very substantial walling, the neat appearance and smooth surfacing of which are apt to be deceptive.

The Method of Mixing.—The ingredients suitable for forming the best pisé-de-terre walling is to take material in the following proportions: 1 part stiff clay; 1 part sharp sand; 2 parts broken stone; and add straw cut to 3–4-inch lengths, which addition serves the purpose of strengthening by binding, and so prevents cracking.

FLINT WALLING

An irregular form of walling is built of flint pebbles set roughly in mortar. The sizes of the flints used range from 8 inches to 9 inches long by 3 inches to 4 inches wide, of irregular shape, but having rounded surfaces. These stones are easily split, and when the split faces are exposed and placed at the outside of the walls, the work is known as "flint knapping."

This last operation is performed by striking the pebble with a knapping hammer, the flint being rested on the workman's knee, protected by a pad of stiff leather. The squaring is done on a steel anvil or on the thick end of a steel wedge, driven into a block of wood.

Rubble Walls are built of unsplit flint pebbles of a larger size. The stones may be roughly flattened on the undersides or used as they come, being bedded into thick layers of mortar. The thickness required for walls, there being only a slight bond in this method of construction, is at least 24 inches. Random rubble in flint is frequently only flint faced, the interior being filled in with a cheaper and softer stone—sometimes chalk is used for this interior filling. Such random walling is best combined with quoins of shaped stonework or brickwork and built on a foundation of concrete. The method of construction employed is to erect on the foundation wood shutters strutted and kept the required distance apart, to give the necessary thickness to the finished wall, by stretchers. The faces of the flints are split off and laid in between the forms with the split face against the shuttering. The face work is carried up 9 inches or so at a time, and the interior is then fitted up and thoroughly grouted with cement mortar in layers 4 inches deep. A certain indefinite kind of bond is introduced internally in laying in these interior stones, and the quoins already mentioned provide a further bond and stiffening at the angles.

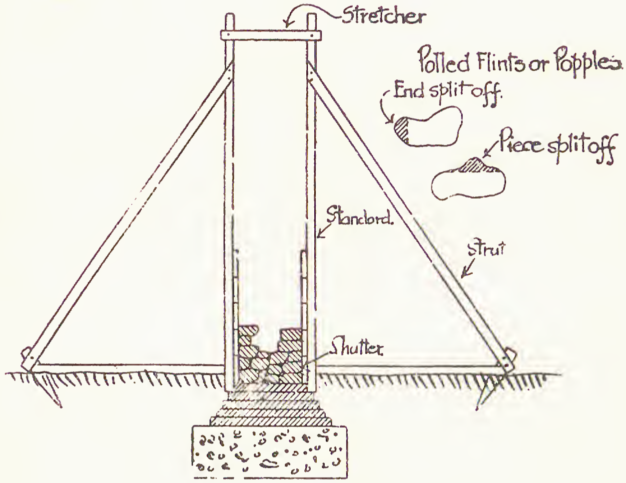


Fig. 129.—Flint walling

CHALK WALLING

Chalk is a limestone consisting of carbonate of lime in a non-crystalline formation. It is of an even granular texture and generally somewhat soft. However, when well tamped it consolidates into very suitable foundations to build on.

It has been used for building walls in blocks and puddled, but it is not to be recommended, owing to the fact that it is rather too readily affected by weather conditions and the acid gases in the atmosphere, such as obtain in the neighbourhood of large cities.

Blocks.—Chalk dug out in blocks and roughly squared is built into walling in a similar manner to that employed in building rubble stonework. A level bed should be maintained to each course in chalk-block walling and the joints made as fine as is possible. Header bonding stones should be introduced every so often in the length and height of the walling, the bond stones extending into the wall three-quarters of the thickness of the wall.

Walls built in chalk blocks require to be at least 20 inches thick on the ground floor and not less than 16 inches thick on the upper floor.

For the same reason as was mentioned in connection with pisé-de-terre, chalk walls should be mounted on some impervious base wall at a height of the ground-floor window sills. The base wall should be built of any of the usual impervious materials such as concrete, stone, or an impervious brick—soft sand-faced bricks should not be used for this purpose. For the same purpose, *i.e.* the protection of the chalk walling from rainwater, the eaves should be given as wide a projection as can be practically constructed.

Quoins and String Courses should be built of brick or stone, and composite walls are sometimes constructed of alternate courses of chalk and flint ; also, alternatively, there is a type of walling formed by alternating blocks of chalk and flintwork, giving to the surface a chequer-board appearance.

Chalk Filling.—Probably the only satisfactory method of using chalk for walling is as a filling between other materials, or to cover the chalk with roughcast or cement stucco. Even then it is questionable whether some kind of piers should not be built in the interior to give additional support to the wall plates carrying the floor joists and roof timbers, as the resistance to compression of chalk is not great. Such piers might well be combined with a string course, under the eaves, built of concrete highly reinforced.

But when all these precautions have been taken it may be open to doubt if any saving has been effected in either time or materials, and unless this is so, there does not seem any reason to give oneself so much trouble with an inferior material when good materials are so readily come by in all but very exceptional districts.

Another substitute form of walling is the *Puddled Chalk Wall.* In this chalk lumps are broken up, mixed with chopped straw, hay, or bracken and water, and trodden into a compact mass in position.

An old system of walling in puddled chalk was to pile up the broken chalk loosely with chopped straw, add water, and then tread until well mixed. A foundation wall was then raised of brick or stone about 2 feet wide and up to at least 9 inches above the ground line. One workman mounted on this foundation wall receives the puddled mixture from another below. This is then deposited on the wall for about 3 feet and well trodden until a depth of 18 inches is so laid. The wall is consolidated and trimmed at the sides with a flat spade. A course is so laid round the whole building, and then in the same manner another course is begun. Quoins of brick, flint, or chalk blocks squared, are built into openings and at angles. The roof, which is often of thatch, has wide eaves.

This method is a very laborious, slow, and antiquated one, which has no particular interest save an historical one. The damage that may be caused by heavy rain, especially during building, and the fact that drying out takes a long time, are sufficient to cause wonder why such a method ever came to be used.

What is considered *an Improved Method*, is to prepare the "mud" by mixing, on a platform of boards, chalk broken to about a 2-inch size with chopped straw and water in quantity equal to about 8 per cent. of the weight of the chalk. When reduced to a stiff plastic mass it is shovelled into position between shuttering to a depth of 3 inches and then rammed with a wedge-shaped iron tamper as used for pisé-de-terre. An advantage in this method over the old-time method is that it does not take long, and the quoins, cornices, and abutments being courses of brick or flint, they can be fixed as the work proceeds.

It is of course very important that any such walling should be extensively dampcoursed, and all wall plates should have a dampcourse material laid under them.

This walling when finished should be roughcast or cement stuccoed.

(*The detail illustrations of terra-cotta in this chapter are reproduced by courtesy of the Hathern Station Brick & Terra-cotta Co., Ltd.*)

CHAPTER 5

STRUCTURAL DESIGN

THE principles of structural mechanics form the basis of all structural design, whatever the materials and systems employed. The chief structural materials are :

Brickwork, masonry, mass concrete, timber, steelwork, reinforced concrete.

Structural systems are of two main types :

(1) Load-bearing walls, with walls over openings carried on arches or lintels.
(2) Framework of stanchions and beams, with panel filling.

For buildings of normal size and purpose in class 1, load-bearing walls, calculations to find thicknesses of walls are not required as the thicknesses are laid down in the building by-laws in accordance with height and length. But for buildings in class 2, that is buildings framed in steelwork or reinforced concrete, calculations are required. All but the smallest timber-frame buildings also require calculations.

PRINCIPLES

Stress.—The weight of the upper part of a structure is supported on the lower part, and it is obvious that this weight increases the lower we take it until it reaches its maximum at foundation level.

The weights of roofs, ceilings, floors, walls, etc., are called *dead loads.* These loads do not vary—once the building is finished they remain constant.

The weights of furniture, stock, machinery, equipment, and the people who use the building vary both in quantity and position. These are called *live loads.*

The various parts of a building must be strong enough to carry both the live loads and the dead loads. Careful consideration must be given to the live loads which the building is likely to carry.

Dead Loads.—These can be calculated from the known weights per square foot for a given thickness, or per cubic foot, for the various materials used. Weight and load data will be found in the final chapter, " Practical Calculations and Useful Data," of Volume IV.

The loads produce stresses in the structural parts or members. Stress may be defined as the load per unit cross-sectional area and is usually calculated in tons per square inch. We may also express it in cwts. or lb. per square inch, but we must be careful to use the same units throughout the calculations.

Compressive Stress.—A load bearing downwards on the vertical axis of a column or wall produces compressive stress which tends to crush the fibres of the material, and we can say that the material is in compression.

Tensile Stress.—A load suspended at the end of a rod or wire produces tensile stress which tends to tear apart the fibres of the material, and we can say that the material is in tension.

Shear Stress.—If two opposite forces act on a material and they are not quite in line, the fibres tend to fail by a sliding action. Material cut by a pair of shears offers a familiar example of failure by shear stress.

Transverse Stress.—This occurs through bending, even though the

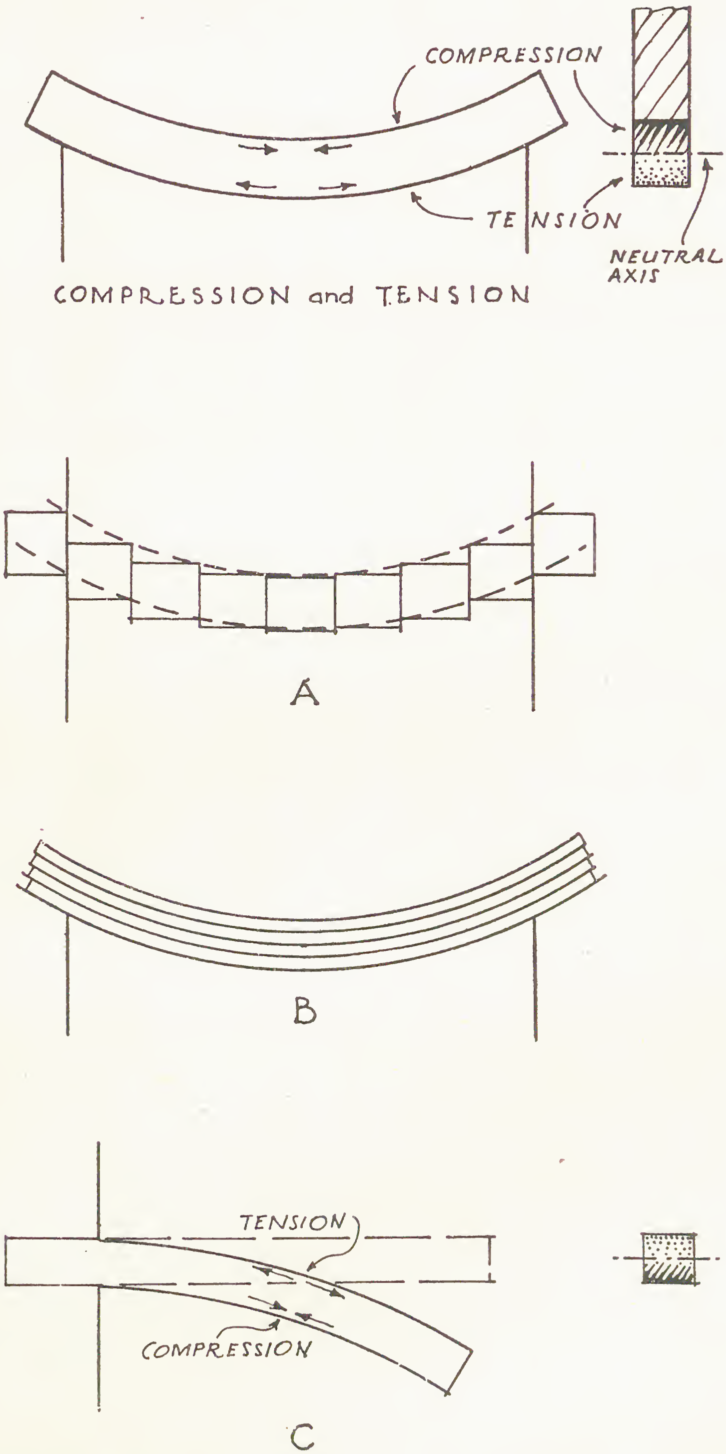


Fig. 130.

bending may be so slight as not to be discernible without the aid of instruments. It is an important effect of loads on beams and pillars.

Bending Stresses in Beams.—Fig. 130 illustrates a loaded beam and the stresses which are produced by bending. In the bent beam the top or inside of the curve is obviously shorter than the bottom or outside of the curve. This shows that the top has been compressed and the bottom stretched. The top part is therefore in compression and the bottom in tension, these stresses being greatest at the top and bottom edges and becoming smaller and smaller as the middle of the beam is approached. Along the *neutral axis*, which runs horizontally through the middle of the beam, there is neither compression nor tension.

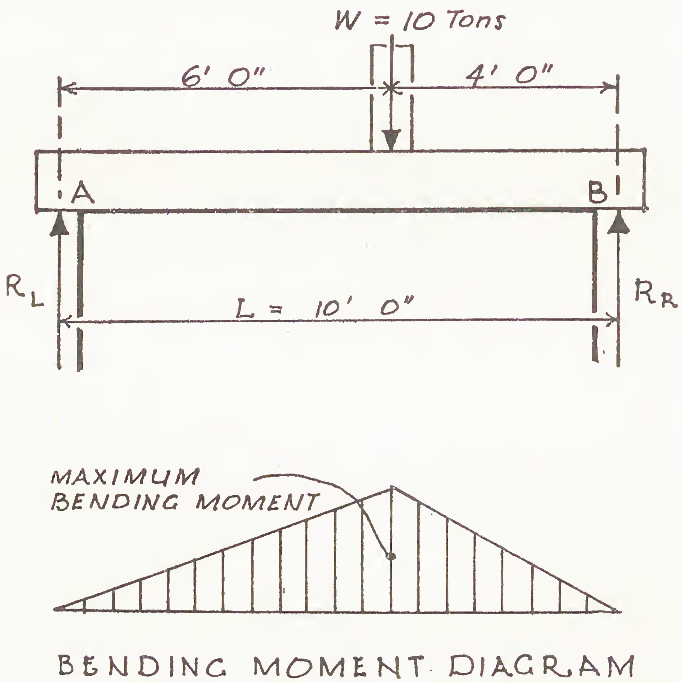


Fig. 131.

Both vertical and horizontal shear stress occur in the beam. The *vertical shear stress* is due to the tendency of the beam to shear under load, particularly near the supported ends. The *horizontal shear stress* is due to the tendency of the fibres to slide over one another as the top of the beam is shortened and the bottom lengthened by bending.

Extreme Fibre Stress.—This occurs at the top and bottom edges of the beam where the compressive and tensile stresses respectively are greatest.

The same stresses due to bending occur in a long pillar. It will be realised that the longer the beam or column in relation to depth or least thickness the greater the stresses due to bending.

Uniform Stress.—This occurs when one kind of stress is distributed uniformly over the cross section of the member. It obviously cannot occur in a beam or long stanchion, but only in a very short mass of material such as a concrete foundation.

Strain.—This is often confused with stress, but strain is an effect of stress. Mathematically it is the amount of alteration in length divided by the original length.

Where F = force or load, A = cross-sectional area, L = original length, and L_1 = alteration in length,

$$\text{Stress} = \frac{F}{A} \text{ and Strain} = \frac{L_1}{L}.$$

Young's Modulus of Elasticity.—This is a useful constant which remains the same for any particular material over the whole range of stress values. It is denoted by the letter E.

$$E = \frac{\text{Stress}}{\text{Strain}} \text{ and}$$

$$\text{Strain} = \frac{\text{Stress}}{E}.$$

The modulus of elasticity (E) for mild steel = 30,000,000 lb. per square inch (13,000 tons per square inch). The value for cement concrete = 2,000,000 to 4,000,000 lb. per square inch according to the strength.

The Moment of a Force.—This is a measure of the effect of leverage and is of great importance in understanding structural mechanics. Mathematically, it is the force multiplied by the distance through which it acts. Pushing open a door is an example of leverage. If you push it close to the hinged side you have to push with greater force than if you push near the free edge, though you must push through a greater distance in the latter case An ordinary house door requires a force of about 10 oz. applied 3 inches from the hinged edge to close it, but applied to the free edge a fraction of an ounce is sufficient owing to the greater leverage.

In both cases the moment of the force is the same. The moment is measured in a unit which combines force and distance : foot/lb., foot/cwt., or foot/ton, care being taken to use the same unit throughout a calculation. In the case of the door we can use the inch-ounce unit, thus :

(A) Force applied 3 inches from hinged edge = 10 oz., so moment of force = 3 × 10 = 30 inch oz.

(B) Force applied 36 inches from hinged edge = ·83 oz., so moment of force = 36 × ·83 = 30-inch oz. (approx.).

The two directions through which moments act are called *clockwise* and *anti-clockwise.*

Reaction.—This occurs when one force is balanced by an equal and opposite force.

A structural member in equilibrium (a state of rest) requires that : (1) The sum of the upward forces must equal the sum of the downward forces ; and (2) The sum of the clockwise moments must equal the sum of the anti-clockwise moments.

Beam Reactions.—Beam loads are transferred to the points of support at each end. The downward force at each support is balanced by the upward reaction. So each reaction equals the load on the support. If

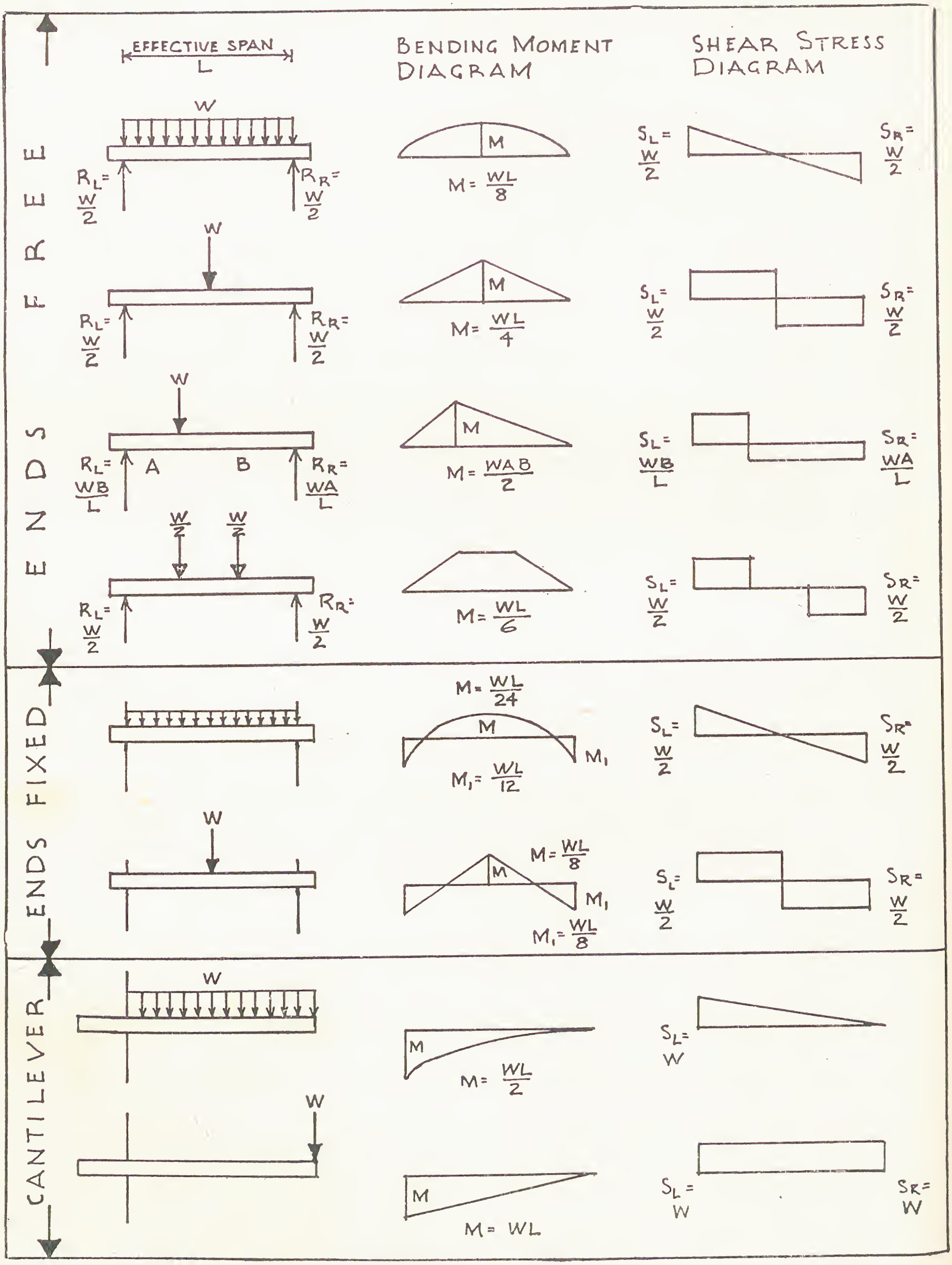

EFFECTIVE SPAN
L
BENDING MOMENT DIAGRAM
SHEAR STRESS DIAGRAM
FREE ENDS
W
M
M = WL/8
R_L = W/2
R_R = W/2
S_L = W/2
S_R = W/2
M = WL/4
A
B
R_L = WB/L
R_R = WA/L
M = WAB/2
S_L = WB/L
S_R = WA/L
W/2
M = WL/6
ENDS FIXED
M = WL/24
M_1
M_1 = WL/12
M = WL/8
M_1 = WL/8
CANTILEVER
M = WL/2
S_L = W
M = WL
S_R = W

Fig. 132.

a beam has a central concentrated load or an evenly distributed load, such load is equally divided between the two end supports. In other words, the reactions are equal and each reaction equals half the load.

If the load is concentrated to one side of the centre or is unevenly distributed the reactions at the end supports are obviously unequal. To find these reactions we use the principle of moments, thus:

If a beam with a span of 10 feet bears a load of 10 tons concentrated 4 feet from one end and 6 feet from the other:

Taking the appropriate formula from Fig. 132,

$$R_R = \frac{WA}{L} = \frac{10 \times 6}{10} = 6 \text{ tons.}$$

$$R_L = \frac{WB}{L} = \frac{10 \times 4}{10} = 4 \text{ tons.}$$

There are many conditions of beam loading. The principal conditions with formulæ for finding reactions are shown in Fig. 132.

Bending Moments.—The bending of a beam is caused by the *bending moment* due to the load and the distance through which the load acts. Under conditions of equilibrium the bending moment is resisted by the *internal resisting moment.*

The bending moment varies through the length of the beam with the condition of loading. Fig. 132 illustrates the chief conditions of loading with the bending-moment diagram for each condition and the formula for finding the maximum bending moment.

The bending-moment diagram is a

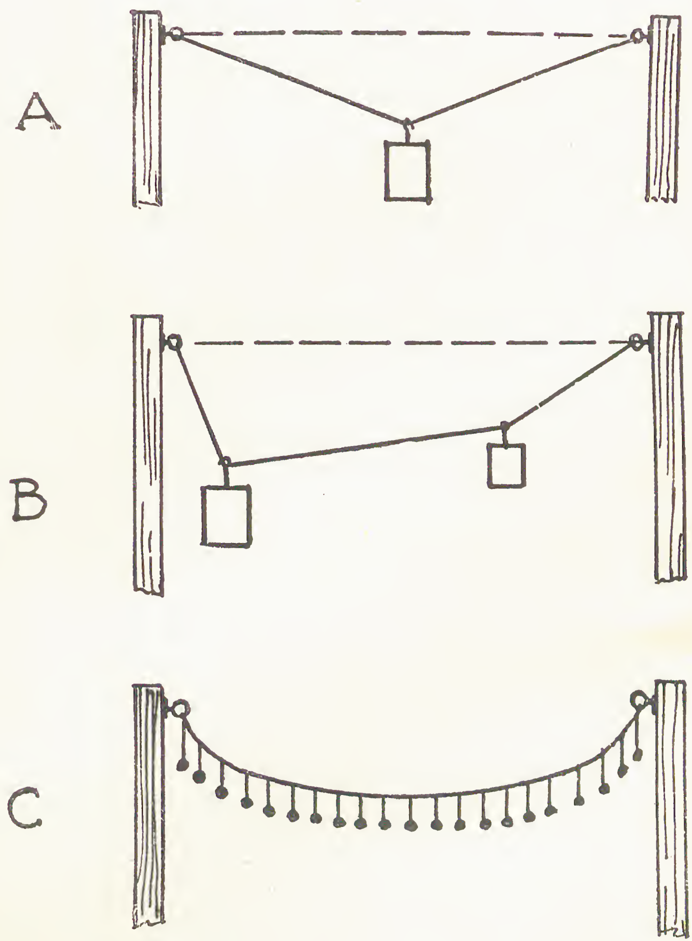


Fig. 133.

graphical representation of the bending moments throughout the beam, the maximum bending moments being indicated by the deepest parts of the diagram. In the formulæ the maximum bending moment is represented by the letter M.

To understand what the bending-moment diagram represents, take a length of string and tie it to supports as shown in Fig. 133. Let the string represent a beam. If you attach a weight to the middle of the string it will be deflected to form a triangular shape. This shape is the same as the bending-moment diagram for that condition of loading. Now, if you attach a large number of equal weights at close intervals the string will bend to an approximate parabolic curve, and this is, in fact, the shape of the bending-moment diagram for an evenly distributed load. The deepest sag of the string is the point where the bending moment is greatest.

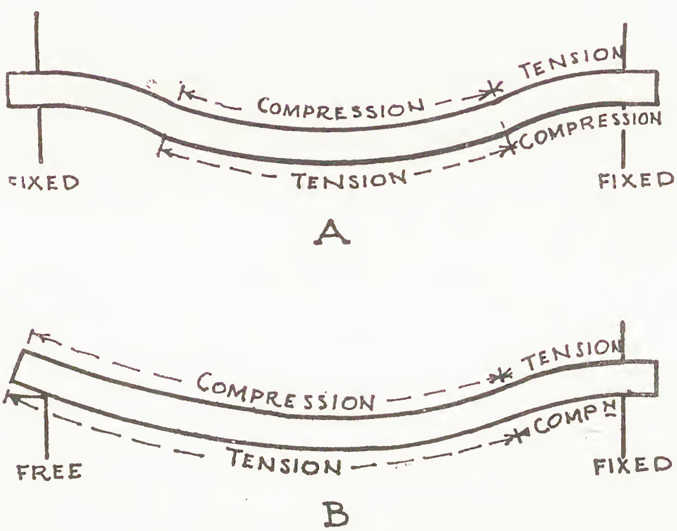


Fig. 134.

The bending-moment diagrams in Fig. 133 indicate the shapes resulting if a length of string is loaded in the manner shown in each case.

Free Ends and Fixed Ends.—The conditions of end fixing affect the shape of the bending-moment diagram. A beam freely supported (with the ends not rigidly fixed) bends to a simple curve, as shown in Fig. 130.

If the ends are rigidly fixed the beam bends to a compound curve, as shown in Fig. 134. In this case the tensile and compressive stresses are reversed near the ends at the points where the curve changes direction. These are called the points of *contraflexure.* The experiments with the piece of string are comparable with the bending of beams with free ends. A very thin wood lath rigidly fixed at both ends by two or three drawing screws, or by clamping, can be used experimentally to represent a beam with fixed ends.

The maximum bending moment is less with fixed ends than with free ends, so fixed ends are more economical as a beam of comparatively small depth may be used to carry the same load. But in practice it is not easy to rigidly fix beam ends. In some cases partial fixing is assumed

It should be easily understood from the foregoing that the shape of the bending-moment diagram is the ideal shape for the beam, but it is rarely convenient to build up such a shape. Beams of uniform section are used, and in these a certain amount of material is wasted.

Shear-stress Diagrams.—These are included in Fig. 132. They illustrate the distribution of vertical shear stress for various conditions of loading and support. Shear stress equals reaction in value, and in Fig. 132 it will be seen that the formulæ are similar.

If the bending moment and shear-stress diagrams are set out to scale so that a unit of measurement, say $\frac{1}{4}$ inch, represents 1 foot ton, then bending moments or shear stresses for intermediate positions can be scaled off.

Moment of Resistance.—As already stated, the bending moment is balanced by the internal resisting moment in a beam in equilibrium. The moment of resistance (R) is the product of the tensile stress in the bottom of the beam and the compressive stress in the top.

The method of calculation depends on the shape of the section. For a rectangular section $R = \frac{bd^2}{6}$. For a rolled-steel joist of I section $R = f \times Ad$, where b = breadth, d = depth, f = maximum safe stress, A = cross-sectional area.

Section Modulus.—This is the moment of resistance for a fibre stress of one unit—say, 1 ton per square inch. The section modulus is denoted by Z. Another way of defining it is that the section modulus is the unit moment of resistance of any particular section of a beam.

So, $R = f \times Z$, where f = maximum stress.

$$Z = \frac{M}{f} \qquad f = \frac{M}{Z} \quad \text{(where M = bending moment).}$$

For any beam which is not a square or round section there is a section modulus for each axis. For example, the rolled-steel joist (*r.s.j.*) H section has a section modulus about the axis XX and another about the axis YY. Values for these moduli are given in the steelwork tables on pages 136 and 137.

The practical significance of the above will now be seen in the following calculations for the strength of timber beams.

TIMBER BEAMS

The strength of a timber beam varies directly as the breadth b, as the square of the depth d, and inversely as the span L.

The London County Council bye-laws allow for redwood of two qualities according to strength: ungraded redwood for which an extreme fibre stress of 800 lb. per square inch is allowed, and graded timbers for which an extreme fibre stress of 1,200 lb. per square inch is allowed. In each case this figure is represented by f.

Example.—Find the sectional dimensions of a freely supported beam of non-graded common redwood with an effective span of 12 feet to carry an evenly distributed load of $12\frac{1}{4}$ cwts.

From Fig. 132 it will be seen that the bending-moment formula for a beam with this condition of loading is

$$M = \frac{WL}{8}.$$

So, using inch-lb. units

$$M = \frac{12{\cdot}25 \times 112 \times 12 \times 12}{8} = 24696.$$

As $M = fZ$, $800Z = 24696$

$$\text{so } Z = \frac{24696}{800} = 30{\cdot}87.$$

As Z for rectangular section is $\frac{bd^2}{6} = 30{\cdot}87$

$$\begin{aligned} bd^2 &= 30{\cdot}87 \times 6 \\ &= 185{\cdot}2 \end{aligned}$$

Now it is necessary to assume a breadth b for the section. This is often dictated by circumstances such as the thickness of a wall to be supported. In this case assume that $b = 4$ inches.

Then from the above $4d^2 = 185{\cdot}2$

$$d^2 = \frac{185{\cdot}2}{4} = 46{\cdot}3$$

$$\begin{aligned} \text{and } d^2 &= 46{\cdot}3 \\ &= 7 \text{ inches, nearly.} \end{aligned}$$

So the beam size required is 7×4 inches.

Other examples of the use of the foregoing formulæ will be found in Chapter 6, " Structural Steelwork."

Factor of Safety.—It may be added that the extreme fibre stress $f = 800$ lb. per square inch allows a factor of safety of about 8. That is, the safe load is one-eighth the breaking load.

The factor of safety allows for unrevealed defects, deterioration, and a measure of overloading. For mild steel the factor allowed is 4, but steel is a more consistently reliable material than timber. Experience shows that a factor of safety of 4 for mild steel and 8 for timber are advisable. These factors also have the advantage of limiting the deflection of beams, so that if plaster ceilings are suspended from them the deflection is not likely to crack the plaster.

PILLARS

Pillars are also called columns, stanchions, and struts. As already explained, long pillars bend under load and the longer the pillar the greater the stresses due to bending. The way in which the load bears on the pillar also affects its strength. A load may be concentric, which means that it bears downwards on the vertical axis ; or eccentric, which means that it bears downwards on one side of the pillar. The method of end fixing (free or fixed, as already explained for beams) further affects the amount and distribution of the bending stresses.

Slenderness Ratio.—This is a measure of the slenderness of the pillar, and the following experiment shows that the slenderness ratio is of great importance : If you take a plasterer's lath and stand it upright

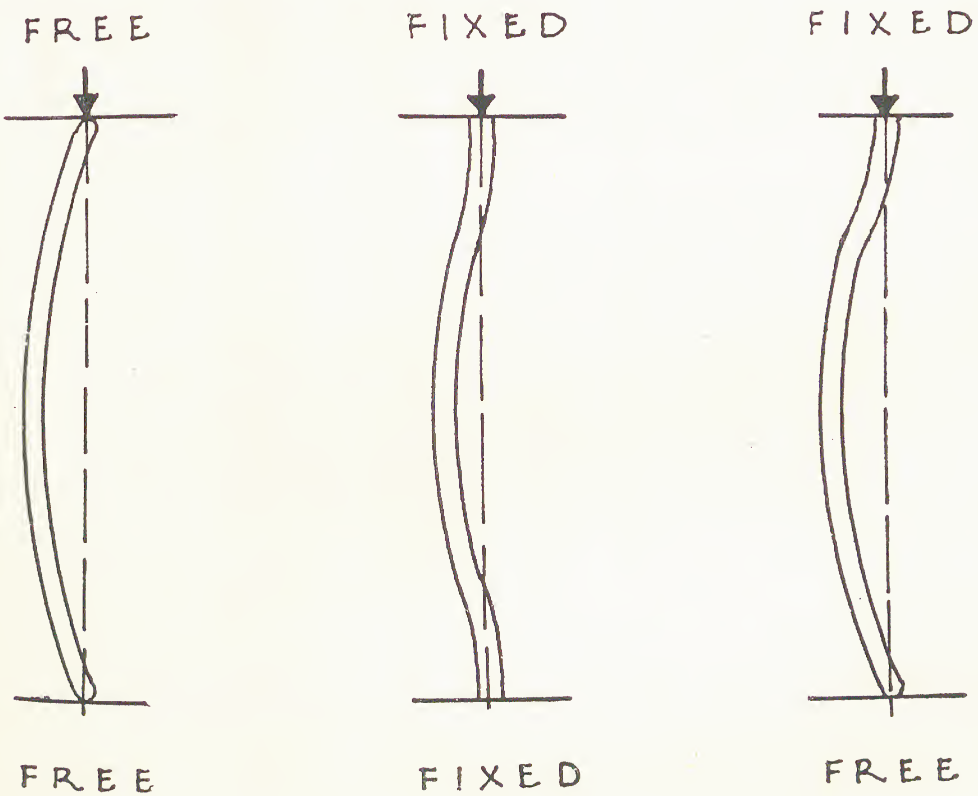


Fig. 135.

you will find that by pressing downwards from the top it bends quite easily, but if you cut off a short length of about 3 inches and apply the same pressure it will not bend. In fact, a long pillar will fail by bending before compressive stress can be built up enough to make it fail by crushing, but a very short pillar will fail by crushing.

Radius of Gyration.—This expression is a measure of the shape and sectional area and dimensions of the pillar. A pillar section having a major and a minor axis has two radii of gyration. In pillar design we may be concerned with the radius of gyration about only one axis or about both, according to the condition of loading.

The slenderness ratio of a pillar $= \dfrac{\text{Length}}{\text{Least radius of gyration}}$.

End Fixing.—The bending of a pillar under load is a simple curve if the ends are free, and a compound curve if the ends are fixed, as in Fig. 135. In the latter case contraflexure occurs with reversal of stresses as already explained for beams with fixed ends.

LOADS ON LINTELS

A lintel is a beam over a doorway, window, or other opening in a wall. It supports the wall above and any floor or roof loads which bear on that portion of the wall supported on the lintel.

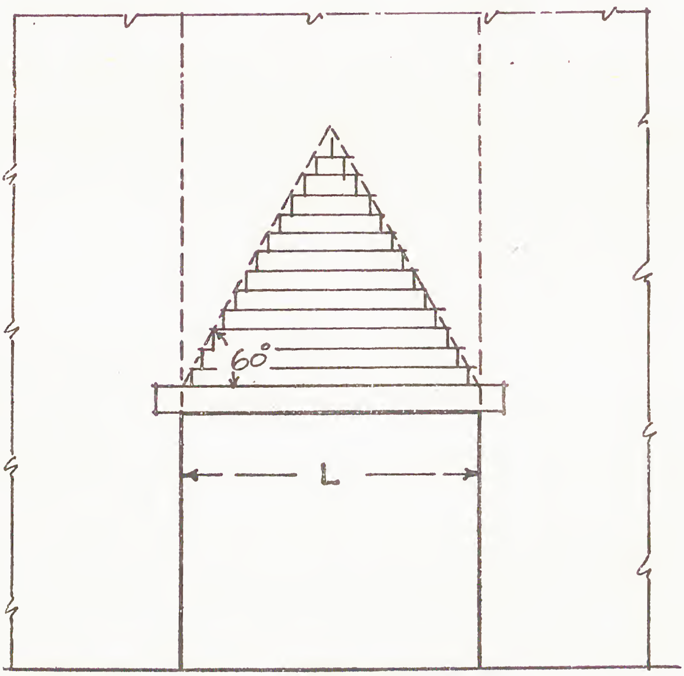


Fig. 136.

Properly bonded brickwork, masonry, or concrete will support itself above an opening if the head of the opening is triangular, as shown in Fig. 136. It is the portion of wall within the triangle which must be supported on the lintel. This applies only where the abutments at the side of the opening are sufficiently strong to resist the diagonal thrust from the wall above the triangle. In practice three conditions are found, and to avoid excessive deflection it is advisable to calculate the wall load according to the following method :

(1) If the wall at each side of the opening is not less than half the width of the opening, allow for wall of height $\frac{L}{2}$ as bearing on the lintel. This, in fact, allows foı the triangle of walling already described.

(2) If the wall on one side of the opening is not less than half the width of the opening and the wall on the other side is less than half the width of the opening, allow for wall of height L as bearing on the lintel. This allows for a square area of walling, each side being equal to the width of opening L.

(3) If the wall on both sides of the opening is less than half the width

of the opening the whole height of the wall is taken as bearing on the lintel, the area of wall to be supported being H × L. This means that we cannot rely on any part of the wall being self-supporting, as it would create diagonal thrust on the abutments which might cause them to spread and so crack the walling joints.

Roof and Floor Loads.—If the floors and roof are not supported on the wall over the lintel they are disregarded, but if they are supported on this wall both the dead and live loads which they bring to bear on the lintel must be added to the dead load of the wall. Normally, half the span of such floors and roof is taken in calculating these loads, the other half being supported at the opposite end.

FRAMES

In framed buildings the loads are supported on trusses, beams, and pillars. Thus the walls are panel fillings and do not support loads. From the strength point of view, the framed building uses material economically, the amount of structural material at any point being in proportion to the load at that point.

Frames may be of timber, steel, or reinforced concrete.

Free and Fixed Joints.—It has already been explained that a beam or pillar with free-end fixing bends in a simple curve, while if the joints are rigidly fixed contraflexure occurs. If a beam is loaded and bends under load in a free or pin-jointed frame, the other structural members are not affected in shape. But if the beams and pillars are rigidly jointed (monolithic), the loading on one beam affects all the structural members.

Rigid Frames.—In practice it is possible to obtain rigid or monolithic frames by welding or by monolithic reinforced concrete. By these systems we can have

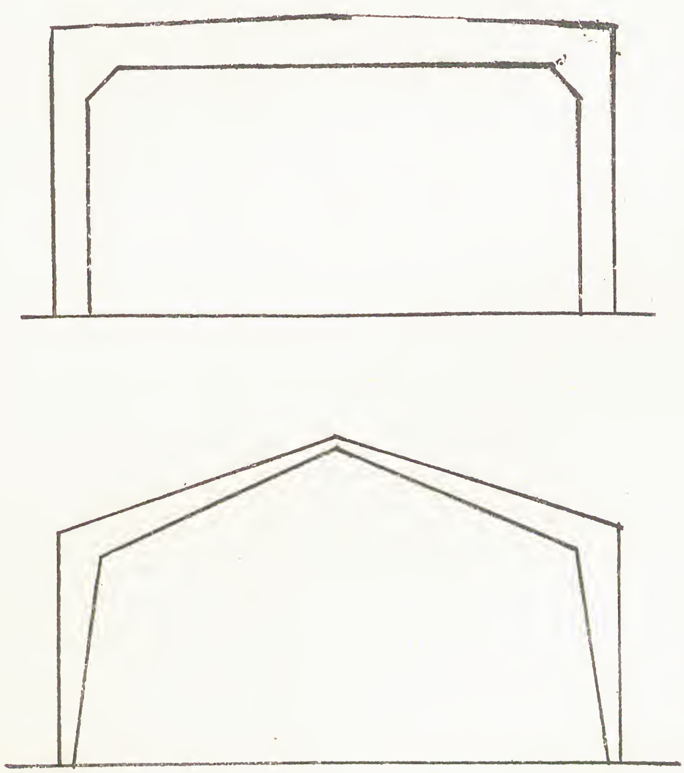


Fig. 137.

combined roof-wall frames, as in Fig. 137. If the joints were free, these structures would collapse.

Principles of Framing.—In a simple span roof, as shown in Fig. 138, the rafters exert a diagonal thrust on the walls or pillars. This thrust can be taken up in three ways: (i) by making a rigid tie joint at the ridge, (ii) by making rigid tie joints at the junction of rafter and pillar head, and (iii) by placing a tie rod across the rafters. Methods (i) and (ii) would make rigid frames. Method (iii) would convert the outward thrust into tension in the tie member. In pitched roofs, method (iii) is usually adopted. In a house roof with timber rafters, for example, the ceiling joists are nailed to the rafters to form the tie member, preventing the thrust of the rafters pushing the walls outwards. The same thing applies to a steel roof truss supported on pillars.

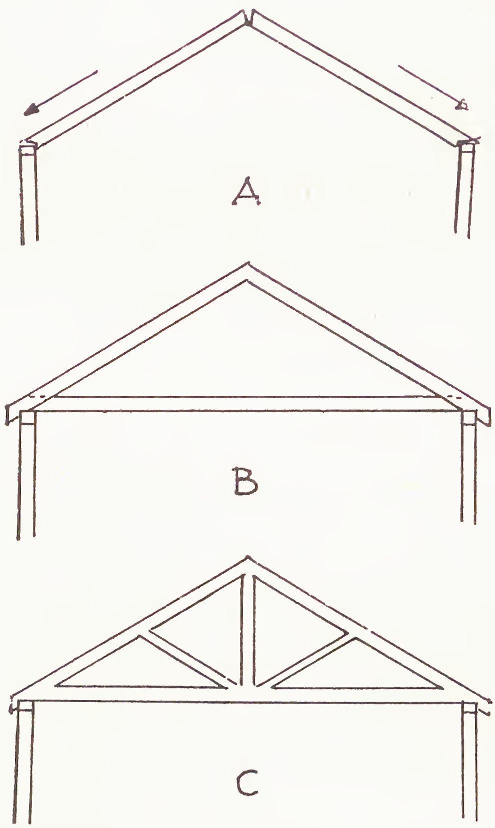


Fig. 138.

Trussing.—A built-up frame to span an opening is called a truss or principal. A truss may be considered as a beam with the unnecessary material cut out. The shape of the bending-moment diagram for a beam with an evenly distributed load has already been illustrated as a parabolic curve (see Fig. 133), the maximum bending moment being at the deepest part of the curve; that is, the middle. The ideal shape for such a beam would be the shape of the bending-moment diagram, but in ordinary beams this is not practicable. In roof trusses, however, we can build up frames which in shape are approximately the same as the bending-moment diagram. The ordinary truss shape for a pitched roof, though not curved, is deepest in the middle where the bending moment is greatest. A curved truss, such as a Belfast or bow-strung truss, is a fairly close approximation to the bending-moment diagram.

In designing a trussed frame the object is to use the minimum amount of material. This is best achieved by placing the various members so that they are either in direct compression or direct tension. Fig. 139 illustrates common types of trusses with the stresses in the members. The principal rafter of a truss is not always in simple compression owing to variations in the direction and pressure of the wind, and sometimes to the placing of purlins between the intersections of principal rafters and struts.

These intersections in frames are called *nodal points.*

It will be seen that the principal rafters are in compression due to the

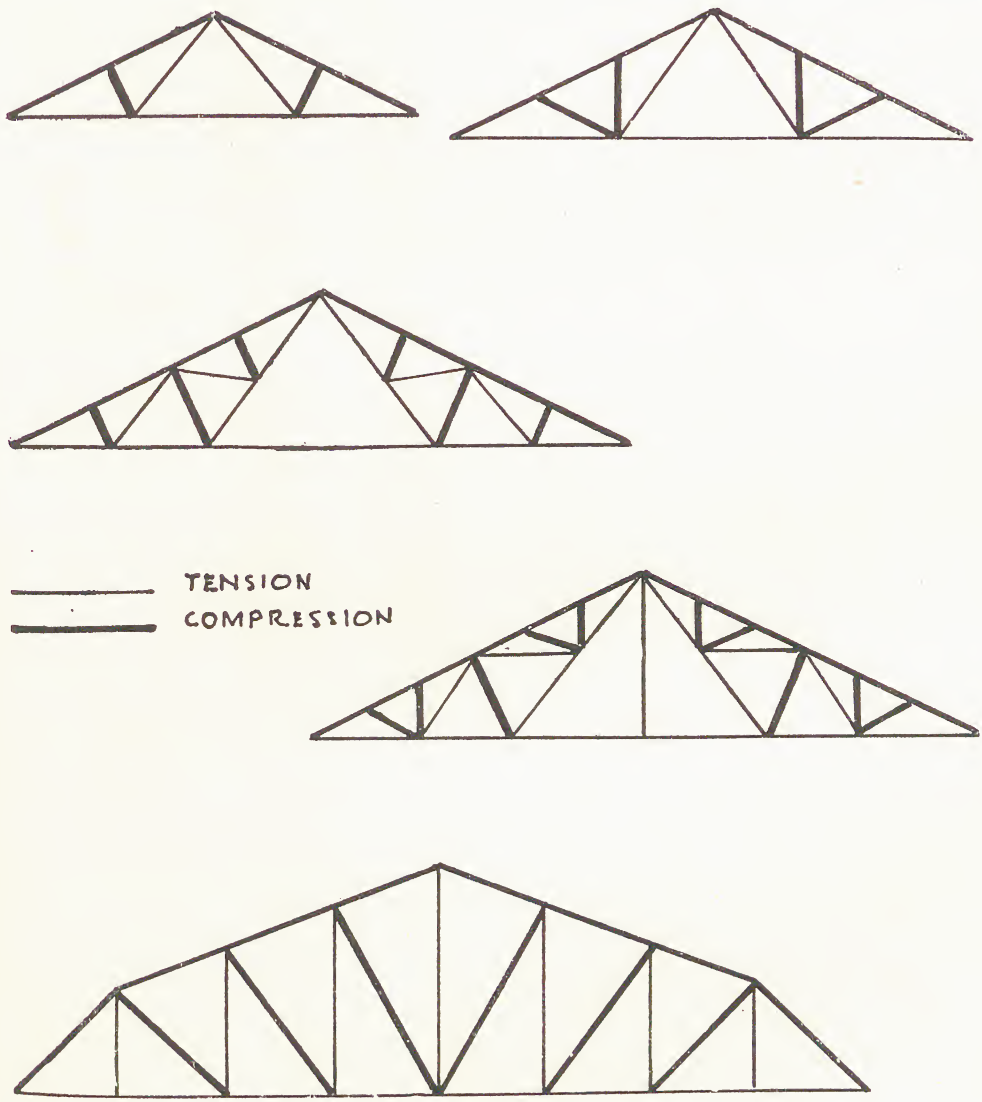


Fig. 139.

weight of roof covering and wind pressure. In addition there are stresses due to bending where purlins are placed between nodal points and wind pressure is uneven.

The outward thrust of the principal rafters is counteracted by the tie member, which is consequently in tension. The principal rafters obtain intermediate support from the struts, and if these struts are placed directly under the purlins the principal rafters are relieved of bending stresses. The struts are in compression. A truss may also incorporate secondary tie members which are in tension. In Fig. 139 various truss

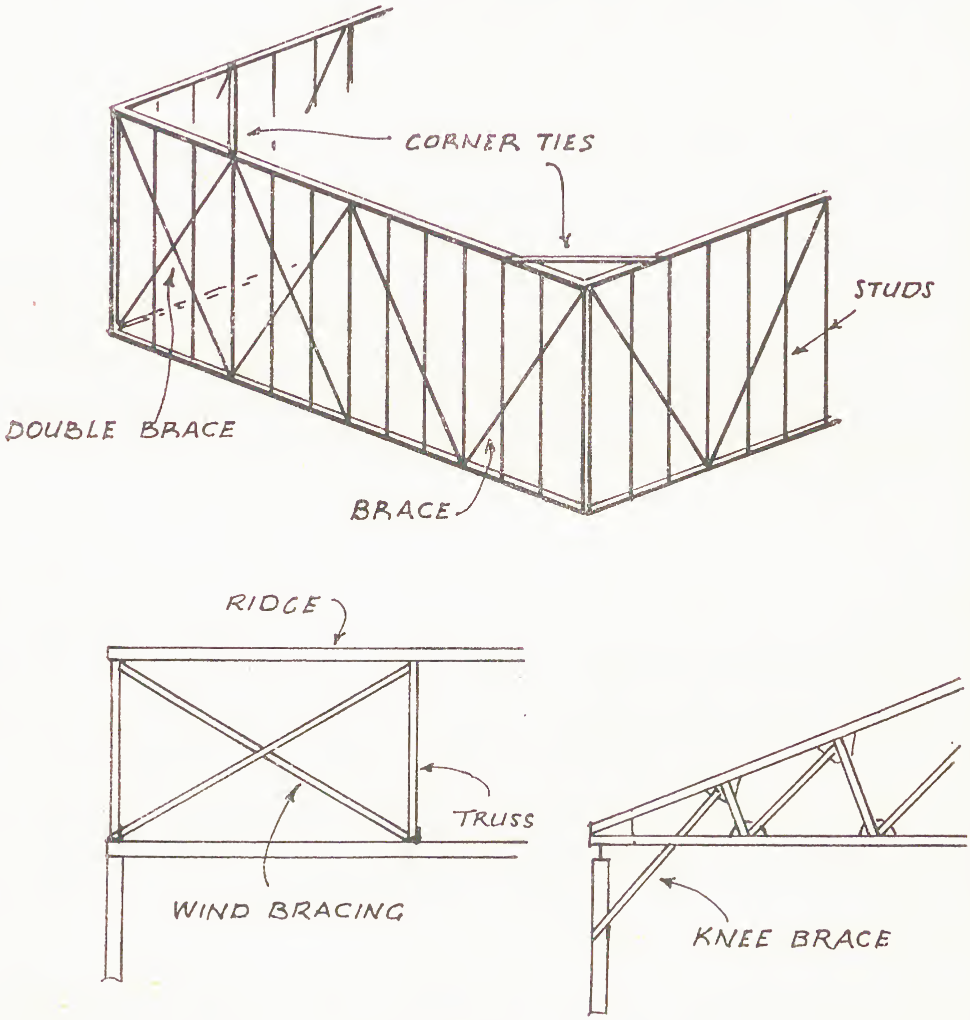


Fig. 140.

designs are shown, members in compression being indicated by heavy lines and members in tension by light lines.

Shell Construction.—Instead of using trusses and purlins, roofs may be constructed as monolithic shells. The shape should be as near as possible to the curve of the bending moment, but as some bending stresses are inevitable the shell must be thick enough to resist these stresses. The advantage of a shell roof is that ties are not needed and the whole interior height is unobstructed and available for use.

Diagonal Framing.—In the roof trusses illustrated in Fig. 139 it will be seen that each truss is divided into a number of triangles. Three members framed to form a triangle are mutually supporting. Each member is supported in position by the other two.

The provision of diagonal members braces a frame, and this principle is extensively used in roofs, walls, bridges, and other framed constructions.

In a framed wall or partition, it is convenient to form a rectangular frame with upright studs or horizontal rails because this gives the required shape and provides a means of fixing the sheeted covering. But unless the joints are rigid the frame may fail by lateral movement. Bracing members fixed diagonally, as shown in Fig. 140, will prevent this.

Heavy wind pressure on one side of a building tends to "fold up" the structure, and bracing is the most economical means of combating this tendency. Roof trusses are often braced to one another down the centre line of the building, and tied to pillars with knee braces. Wall frames are often braced at the corners, as in Fig. 140.

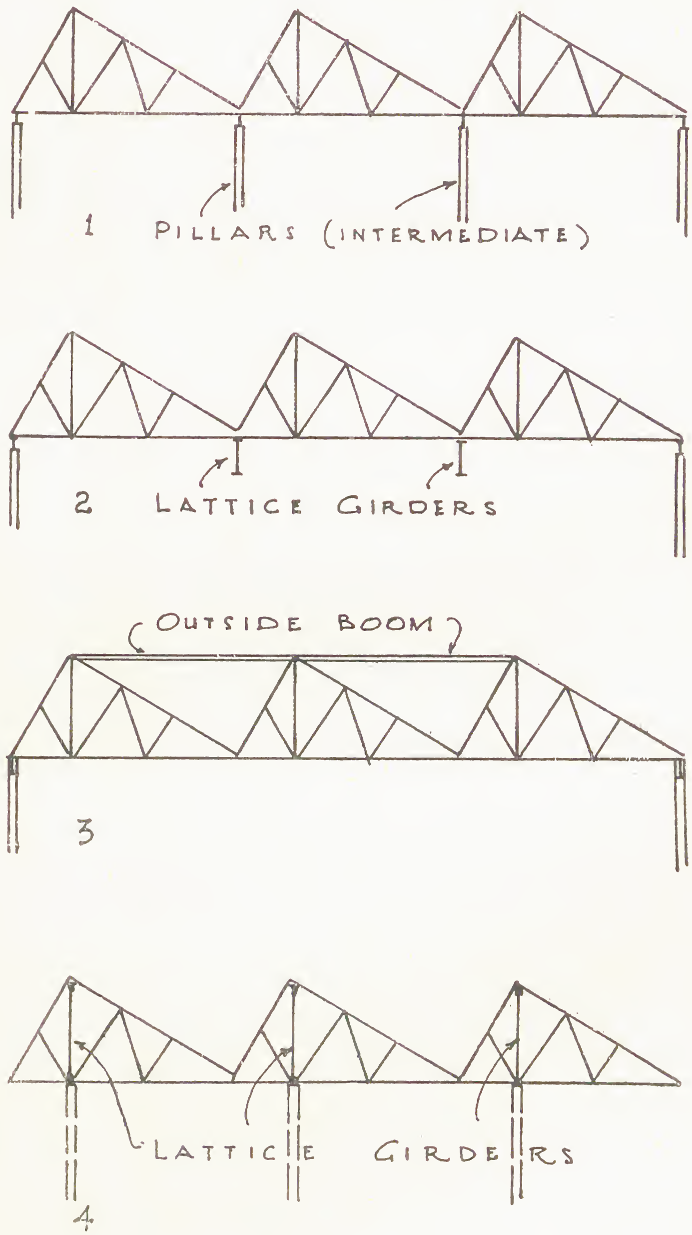


Fig. 141.

North-light Roofs.—Direct sunlight is undesirable in factories and offices. For this reason an extensive floor area covered by an open roof (without suspended ceiling) is usually provided with daylight illumination by glazing the northerly side only of a pitched roof.

To meet these requirements the north-light or saw-tooth roofs illustrated in Fig. 141 have been designed. They consist of a series of spans, each with a low-pitched side and a steep-pitched side, the latter being placed on the northerly aspect and glazed.

There are four systems of support. The first, illustrated in Fig. 141, provides direct support on rows of intermediate columns. The second has deep lattice girders for the intermediate support, thus leaving the floor space clear of columns. If lattice girders would cut down the headroom below a convenient height, the third method, in which the trusses are converted into a framed girder by the addition of an outside boom, is used. Alternatively, the fourth method, in which the trusses are cantilevers supported on deep lattice girders placed longitudinally in the depth of the roof, may be used. This is especially useful for open "shed" buildings where the columns must be kept down to a minimum to give as much clear floor space as possible.

CHAPTER 6

STRUCTURAL STEELWORK

THE principles of framed construction described in Chapter 5 apply to frames of steelwork.

Materials.—Mild steel complying with British Standard Specification No. 15 is used for most structural-steelwork purposes. This material has a maximum safe working stress of 8 tons per square inch. During the war this maximum permissible stress was increased to 10 tons per square inch for industrial and single-storey buildings.

High-tensile steel, though more costly than mild steel, is stronger, so lighter sections can be used for given loads. This results in a saving of weight and space which is advantageous for certain buildings and such structures as bridges. The maximum working stress for high-tensile steel is generally taken as 50 per cent. greater than that for mild steel.

Regulations.—Design and construction in steelwork are governed in the London County Council area by the L.C.C. by-laws for the construction and conversion of buildings under the London Building Act, 1930–39.

Outside London, British Standard Specification No. 499 (The Use of Structural Steel in Buildings) should be accepted. The Ministry of Health Model By-Laws, Series IV, Buildings, 1952, require that steelwork shall be designed in accordance with B.S.S. 499.

DESIGN

Layout.—A steel frame building consists of a grid of steel beams and pillars. These members consist of single H or other sections, where the loads are light to moderate and the spans and heights are reasonably short. For heavy loads and/or wide spans, sections have to be built up or plated from several individual sections by riveting or welding them together. In some cases it is economical to frame the pillars and beams.

Flat roofs are framed with H or plated girders where the spans are short, but to cover a wide span without intermediate columns lattice girders are necessary. In the case of pitched roofs framed trusses are used.

Pillar Spacing.—For economy the pillars should be spaced at about 20-foot centres each way. In some buildings, however, wide unobstructed floor areas are required. This necessitates the use of heavy plated pillars and girders and increases the cost of the steelwork per cubic foot of building.

The layout should be as simple as possible, and is most economical when pillar and beam lengths can be repeated. This means that the steelwork must be planned to a regular " grid," pillars being evenly spaced throughout. Here again economy must sometimes be sacrificed to convenience in the use of the building, and to the peculiarities of the site.

Procedure.—Small steelwork structures are sometimes designed by the architect, but it is usual for the architect to obtain steelwork designs and tenders from structural-steelwork firms. The disadvantage of this method is that each firm prepares its own scheme so that the tenders are not prepared on a common basis and are therefore difficult to compare. The cheapest scheme may not be the best.

The consulting structural engineer is a specialist designer in independent practice. It is usual for architects to have steelwork designs for large buildings prepared by such a specialist, and it is advisable to have even small structures so designed. Tenders can then be obtained on a common basis and a true comparison of prices can be made.

The structural engineer should be supplied with a set of plans which show all the walls, floors and roofs, positions and weights of any heavy machines or equipment, suggested positions of pillars (or a statement of the minimum pillar spacings), and either the live floor loads or the purpose for which the floors are required. Overall dimensions and positions of doors and windows should be accurately figured.

The structural engineer then prepares a suggested scheme in outline. He may suggest that minor revisions should be made to the architect's plans to enable desirable economies in steelwork to be effected. At this stage the various specialists responsible for the major equipment (heating and ventilating, machinery, sanitary equipment, etc.) should be consulted, as they may require modifications to the steelwork. The structural engineer then prepares a final layout and proceeds to make large-scale details. His drawings and calculations must be submitted to the local authority, whose engineers may require modifications.

It will be realised that it is not desirable to alter the plans of the building once the structural engineer has detailed his scheme, as a lot of work and delay may be involved in preparing a revised scheme.

ROLLED-STEEL JOISTS

Although steelwork design is a specialist's job, architects and builders sometimes have to select-r.s.j. sizes for lintels, bressumers and floor beams. This is a fairly simple matter if the steelwork tables printed herewith are used.

Explanation of Tables.—The tables give the safe evenly distributed load for various standard rolled-steel joist sections and various spans. It is assumed that the beams are freely (not rigidly) supported at the ends. A beam with ends built into a brick wall counts as a beam freely supported. The span is the effective span taken from the centre of the bearing. A bearing of 9 inches at each end is usually sufficient for moderate loads, so the effective span is then 9 inches longer than the clear span.

The tabular loads apply to mild steel for an extreme fibre stress of 8 tons per square inch.

Evenly Distributed Loads.—For even distribution the safe load can be read under the span. No calculations are required.

For example, select a suitable r.s.j. section for an evenly distributed load of $14\frac{1}{2}$ tons over an effective span of 10 feet.

Under the 10-foot span column it will be found that a load of 15·6 tons can be safely supported by a section 10 × 5 inches × 30 lb. (the last figure meaning that the weight of the r.s.j. is 30 lb. per foot run). Farther down the column it will be seen that an 8 × 6 inches × 35 lb. section will support 15·3 tons. As the strength of both sections is adequate, the lighter section should be selected, that is the 10 × 5 inches × 30 lb.

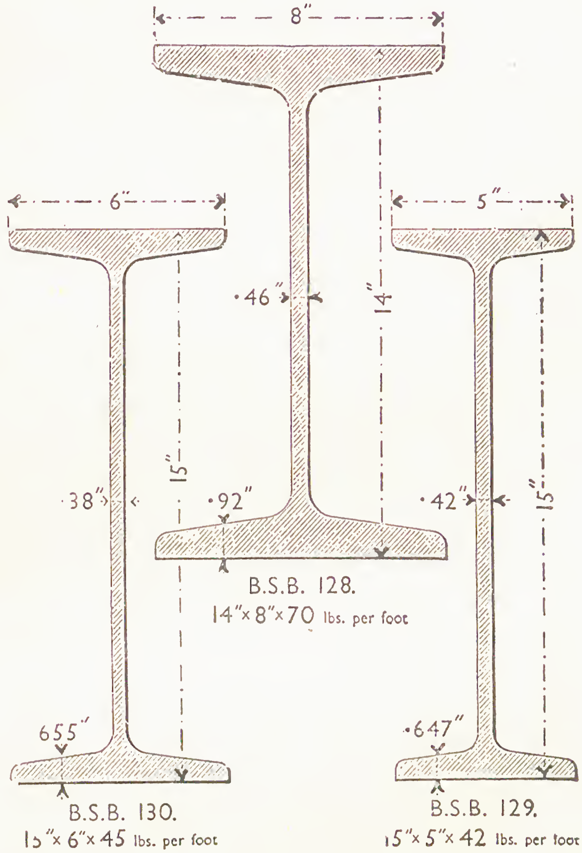


Fig. 142.

Unevenly Distributed Loads.—If the load is unevenly distributed, the stresses due to bending are greater (see Chapter 5). Before using the tables the equivalent distributed load must be found, and for this we must first calculate the maximum bending moment or the required modulus of the section. These terms have been explained in Chapter 5. Both methods will now be explained and demonstrated.

Example, using the Maximum Bending Moment.—A central concentrated load of 7 tons has to be carried over a span of 12 feet on a r.s.j. with freely supported ends. Find the required r.s.j. section.

First find the maximum bending moment M. From the loading diagram in Fig. 132 (page 118)

$$M = \frac{WL}{4} = \frac{7 \times 12}{4} = 21 \text{ feet-tons.}$$

If the load was uniformly distributed, M would $= \frac{WL}{8}$.

So, equivalent distributed load $= \frac{M \times 8}{L} = \frac{21 \times 8}{12} = 14$ tons.

From this it follows that a load concentrated in the middle of a beam has twice the effect of the same load evenly distributed.

From the table of safe distributed loads it will be seen that a 12×5 inches $\times$ 32 lb. r.s.j. will carry 16·3 tons over a span of 12 feet. This is the nearest section suitable.

Example, using the Modulus of Section.—This method is simpler. We have to find the required modulus of section Z. On page 121 we have shown that $Z = \frac{M}{f}$.

The maximum safe stress f for mild steel is 8 tons per square inch. Now as we are taking f in tons per square inch we must take M in inch-ton units (not foot-ton units as in the example above. Throughout a given calculation we must keep to inch units or foot units and not attempt to mix both).

So,
$$M = \frac{ML}{4} = \frac{7 \times 144}{4} = 252 \text{ inch-tons.}$$
$$Z = \frac{M}{f} = \frac{252}{8} = 31{\cdot}5.$$

From the table of properties the nearest Z to the above figure is 36·84, which is for a r.s.j. $12 \times 5 \times 32$ lb. This, of course, is the same result as obtained by the previous method.

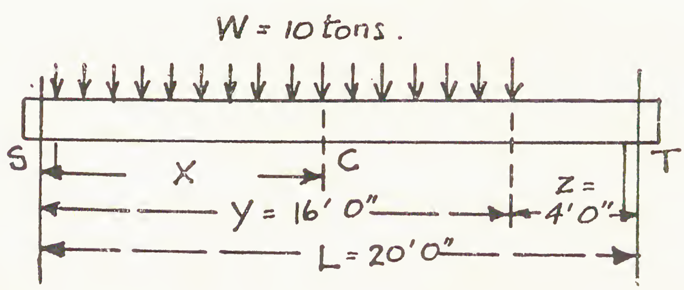


Fig 143.

Example of a Load Distributed over a Portion of the Beam.—We have seen that a beam may be loaded more heavily on one side of the centre than the other.

The following example is of a beam carrying a uniformly distributed load over a portion of its length, as in Fig. 143, extending from one support to within 4 feet of the other.

The load W is 10 tons and the effective span 20 feet. The load is uniformly distributed for 16 feet from one side.

R_1 = reaction at end S where load commences.
R_2 = reaction at opposite end T.
C = point where maximum bending moment M occurs.
x = distance in feet of C from S.
P = distributed load on length x.
W_E = equivalent distributed load over whole length of beam which would produce the same maximum bending moment as that caused by load W.

To find the reactions at the point of supports,

$$R_1 = \frac{W\left(\frac{y}{2} + z\right)}{L} = \frac{10\,(8 + 4)}{20} = 6 \text{ tons.}$$

Formula for finding point C at which maximum bending moment occurs:

$$x = y\left(1 - \frac{y}{2L}\right) = 16\left(1 - \frac{16}{2 \times 20}\right) = 9{\cdot}6 \text{ feet.}$$

$$P = \frac{Wx}{y} = \frac{9{\cdot}6 \times 10}{16} = 6 \text{ tons.}$$

Maximum bending moment

$$= (R_1 \times x) - \left(P \times \frac{x}{2}\right) = 6 \times 9{\cdot}6 - 6 \times 4{\cdot}8 = 21{\cdot}8 \text{ feet-tons.}$$

Maximum bending moment for beam with uniformly distributed load:

$$M = \frac{WL}{8}.$$

Therefore equivalent distributed load

$$W_E = \frac{\text{maximum bending moment in feet-tons} \times 8}{L}.$$

Hence W in this case $= \dfrac{28{\cdot}8 \times 8}{20} = 11{\cdot}52$ tons.

Reference to the table of safe distributed loads on beams will show that r.s.j. 13 × 5 inches × 35 lb. is capable of carrying 11·6 tons at 20-foot span; and as half the maximum load given in the table for this beam $\left(\frac{35{\cdot}5}{2} = 17{\cdot}75 \text{ tons}\right)$ is greater than the maximum reaction R_1 (6 tons), this beam will meet the requirements.

Instead of finding the equivalent distributed load the required section modulus Z can be found as follows:

$$Z = \frac{M}{f} = \frac{21{\cdot}8 \times 12}{8} = 42.$$

ROLLED-STEEL JOISTS (f = 8 tons per sq. in.)

(British Steelwork Association Tables)

Safe Distributed Loads, in Tons

Size $d \times b$ inches	Spans in feet: 10	12	14	16	18	20	22	24	26	28	30	32	36	40
24 × 7½	112	93·8	80·4	70·3	62·5	56·2	51·1	46·9	43·2	40·2	37·5	35·1	31·2	28·1
22 × 7	81·2	67·7	58·0	50·8	45·1	40·6	36·9	33·8	31·2	29·0	27·0	25·4	22·5	20·3
20 × 7½	89·2	74·3	63·7	55·7	49·5	44·6	40·5	37·1	34·3	31·8	29·7	27·8	24·7	22·3
20 × 6½	65·3	54·4	46·7	40·8	36·3	32·6	29·7	27·2	25·1	23·3	21·7	20·4	18·1	16·3
18 × 8	76·5	63·8	54·6	47·8	42·5	38·2	34·8	31·9	29·4	27·3	25·5	23·9	21·2	17·2
18 × 7	68·2	56·8	48·7	42·6	37·8	34·1	31·0	28·4	26·2	24·3	22·7	21·3	18·9	15·3
18 × 6	49·8	41·5	35·6	31·1	27·7	24·9	22·6	20·7	19·1	17·8	16·6	15·5	13·8	11·2
16 × 8	64·9	54·1	46·3	40·5	36·0	32·4	29·5	27·0	24·9	23·1	21·6	20·2	16·0	12·9
16 × 6_H	48·3	40·2	34·5	30·2	26·8	24·1	21·9	20·1	18·5	17·2	16·1	15·1	11·9	9·6
16 × 6_L	41·2	34·3	29·4	25·7	22·8	20·6	18·7	17·1	15·8	14·7	13·7	12·8	10·1	8·2
15 × 6	34·9	29·1	24·9	21·8	19·4	17·4	15·9	14·5	13·4	12·4	11·6	10·2	8·0	
15 × 5	30·4	25·3	21·7	19·0	16·9	15·2	13·8	12·6	11·7	10·8	10·1	8·9	7·0	
14 × 8	53·7	44·7	38·3	33·5	29·8	26·8	24·4	22·3	20·6	19·1	16·7	14·7		
14 × 6_H	40·6	33·8	29·0	25·3	22·5	20·3	18·4	16·9	15·6	14·5	12·6	11·1		
14 × 6_L	33·7	28·0	24·0	21·0	18·7	16·8	15·3	14·0	12·9	12·0	10·4	9·2		
13 × 5	23·2	19·3	16·6	14·5	12·9	11·6	10·5	9·6	8·9	7·7	6·7			
12 × 8	43·3	36·1	30·9	27·0	24·0	21·6	19·7	18·0	15·3	13·2				
12 × 6_H	33·4	27·8	23·8	20·8	18·5	16·7	15·1	13·9	11·8	10·2				
12 × 6_L	28·1	23·4	20·1	17·5	15·6	14·0	12·7	11·7	9·9	8·6				
12 × 5	19·6	16·3	14·0	12·2	10·9	9·8	8·9	8·1	6·9	6·0				

Dimensions and Properties

Size $d \times b$ inches	Weight per ft. in lb.	Area in sq. ins.	Standard Thicknesses: Web	Standard Thicknesses: Flange	Moments of Inertia: Axis x—x Max.	Moments of Inertia: Axis y—y Min.	Moduli of Section: Axis x—x Max.	Moduli of Section: Axis y—y Min.	Safe Distributed Load on 1 ft. Span	Deflection Co-efficient
24 × 7½	95	27·94	·57	1·011	2533·04	62·54	211·09	16·68	1125·8	·000769
22 × 7	75	22·06	·50	·834	1676·80	41·07	152·44	11·73	813·0	·000839
20 × 7½	89	26·19	·60	1·010	1672·85	62·54	167·29	16·68	892·2	·000923
20 × 6½	65	19·12	·45	·820	1226·17	32·56	122·62	10·02	654·0	·000923
18 × 8	80	23·53	·50	·950	1292·07	69·43	143·56	17·36	765·7	·001026
18 × 7	75	22·09	·55	·928	1151·18	46·45	127·91	13·30	682·2	·001026
18 × 6	55	16·18	·42	·757	841·76	23·64	93·53	7·88	498·8	·001026
16 × 8	75	22·06	·48	·938	973·91	68·30	121·74	17·08	649·3	·001154
16 × 6	62	18·21	·55	·847	725·05	27·14	90·63	9·05	483·4	·001154
16 × 6	50	14·71	·40	·726	618·09	22·47	77·26	7·49	412·1	·001154
15 × 6	45	13·24	·38	·655	491·91	19·87	65·59	6·62	349·8	·001231
15 × 5	42	12·36	·42	·647	428·49	11·81	57·13	4·72	304·7	·001231
14 × 8	70	20·59	·46	·920	705·58	66·67	100·80	16·67	537·6	·001319
14 × 6	57	16·78	·50	·873	533·34	27·94	76·19	9·31	406·3	·001319
14 × 6	46	13·59	·40	·698	442·57	21·45	63·22	7·15	337·2	·001319
13 × 5	35	10·30	·35	·604	283·51	10·82	43·62	4·33	232·6	·001420
12 × 8	65	19·12	·43	·904	487·77	65·18	81·30	16·30	433·6	·001538
12 × 6	54	15·89	·50	·883	375·77	28·28	62·63	9·43	334·0	·001538
12 × 6	44	13·00	·40	·717	316·76	22·12	52·79	7·37	281·5	·001538
12 × 5	32	9·45	·35	·550	221·07	9·69	36·84	3·88	196·5	·001538

ROLLED-STEEL JOISTS (f = 8 tons per sq. in.)

(British Steelwork Association Tables)

Safe Distribution Loads, in Tons

Size $d \times b$ inches	Spans in Feet: 3	4	5	6	7	8	9	10	11	12	14	16	18	20
10×8							34·2	30·7	27·9	25·6	21·9	19·2	17·1	15·3
10×6					31·2	27·3	24·2	21·8	19·8	18·2	15·6	13·6	12·1	10·9
10×5			31·2	26·0	22·2	19·5	17·3	15·6	14·1	12·9	11·1	9·7	8·6	7·8
10×4½			26·1	21·7	18·6	16·3	14·4	13·0	11·8	10·8	9·3	8·1	7·2	6·5
9×7						30·8	27·4	24·6	22·4	20·5	17·6	15·4	13·7	11·1
9×4		24·0	19·2	16·0	13·7	12·0	10·6	9·6	8·7	8·0	6·8	6·0	5·3	4·3
8×6				25·5	21·9	19·1	17·0	15·3	13·9	12·7	10·9	9·5	7·5	6·1
8×5			23·9	19·9	17·0	14·9	13·2	11·9	10·8	9·9	8·5	7·4	5·9	4·7
8×4		18·5	14·8	12·3	10·5	9·2	8·2	7·4	6·7	6·1	5·2	4·6	3·6	2·9
7×4		15·0	12·0	10·0	8·6	7·5	6·6	6·0	5·4	5·0	4·3	3·2	2·6	
6×5		19·4	15·5	12·9	11·0	9·7	8·6	7·7	7·0	6·4	4·7	3·6		
6×4½	20·5	15·4	12·3	10·2	8·8	7·7	6·8	6·1	5·6	5·1	3·7	2·8		
6×3	12·4	9·3	7·4	6·2	5·3	4·6	4·1	3·7	3·3	3·1	2·2	1·7		
5×4½		13·3	10·6	8·8	7·6	6·6	5·9	5·3	4·4	3·7				
5×3	9·7	7·2	5·8	4·8	4·1	3·6	3·2	2·9	2·4	2·0				
4¾×1¾	5·0	3·7	3·0	2·5	2·1	1·8	1·6	1·4	1·1					
4×3	6·9	5·1	4·1	3·4	2·9	2·5	2·0	1·6						
4×1¾	3·2	2·4	1·9	1·6	1·3	1·2	·96	·78						
3×3	4·5	3·3	2·7	2·2	1·6	1·2								
3×1½	1·9	1·4	1·1	·98	·72	·55								

Dimensions and Properties

Size $d \times b$ inches	Weight per ft. in lb.	Area in sq. ins.	Standard Thicknesses: Web	Standard Thicknesses: Flange	Moments of Inertia: Axis x—x Max.	Moments of Inertia: Axis y—y Min.	Moduli of Section: Axis x—x Max.	Moduli of Section: Axis y—y Min.	Safe Distributed Load on 1 ft. Span	Deflection Coefficient
10 ×8	55	16·18	·40	·783	288·69	54·74	57·74	13·69	307·9	·001846
10 ×6	40	11·77	·36	·709	204·80	21·76	40·96	7·25	218·5	·001846
10 ×5	30	8·85	·36	·552	146·23	9·73	29·25	3·89	156·0	·001846
10 ×4½	25	7·35	·30	·505	122·34	6·49	24·47	2·88	130·5	·001846
9 ×7	50	14·71	·40	·825	208·13	40·17	46·25	11·48	246·7	·002051
9 ×4	21	6·18	·30	457	81·13	4·15	18·03	2·07	96·2	·002051
8 ×6	35	10·30	·35	·648	115·06	19·54	28·76	6·51	153·4	·002308
8 ×5	28	8·28	·35	·575	89·69	10·19	22·42	4·08	119·6	·002308
8 ×4	18	5·30	·28	·398	55·63	3·51	13·91	1·75	74·2	·002308
7 ×4	16	4·75	·25	·387	39·51	3·37	11·29	1·69	60·2	·002637
6 ×5	25	7·37	·41	·520	43·69	9·10	14·56	3·64	77·7	·003077
6 ×4½	20	5·89	·37	·431	34·71	5·40	11·57	2·40	61·7	·003077
6 ×3	12	3·53	·23	·377	20·99	1·46	7·00	·97	37·3	·003077
5 ×4½	20	5·88	·29	·513	25·03	6·59	10·01	2·93	53·4	·003692
5 ×3	11	3·26	·22	·376	13·68	1·45	5·47	·97	29·2	·003692
4¾×1¾	6·5	1·91	·18	·325	6·73	·26	2·83	·30	15·1	·003887
4 ×3	10	2·94	·24	·347	7·79	1·33	·3·89	·88	20·7	·004615
4 ×1¾	5	1·47	·17	·239	3·66	·19	1·83	·21	9·76	·004615
3 ×3	8·5	2·52	·20	·332	3·81	1·25	2·54	·83	13·5	·006154
3 ×1½	4	1·18	·16	·249	1·66	·13	1·11	·17	5·92	·006154

(As 21·8 is the bending moment in feet-tons it must be multiplied by 12 to convert to inch-tons, the latter being the units used in the table.)

Reference to the table of properties shows that a 13 × 5 inches × 35 lb. r.s.j. has a section modulus of 43·62 on axis *x.x.*, so this is suitable.

Deflection.—A beam bends under load, even though the deflection may not be discernible. In the steelwork tables reproduced herewith the deflection has been limited to 1/325th of the span, corresponding to a ratio of depth to span of 24. This limit is shown by the full zigzag line. Tabular loads to the right of this line have been reduced in value so that the deflection does not exceed 1/325th of the span.

Tabular loads to the left of the dotted zigzag line are in excess of the safe web buckling value of the beam webs, and for these loads web stiffeners would be required.

Deflection Coefficient.—The coefficient given in the table of properties when multiplied by the square of the span in feet gives the maximum deflection in inches when the beam is fully loaded with a uniformly distributed load, the beam ends being freely supported. These coefficients are for a modulus of elasticity of 13,000 tons per square inch.

CHAPTER 7

CONCRETE CONSTITUENTS

CONCRETE is produced by mixing an aggregate with cement, adding water and mixing again to form a plastic material which is then placed in position and left to set and harden.

There are dense, hard concretes of great strength, porous concretes of medium or low strength, and light-weight concretes. The nature and strength of the material depend upon the kind of constituents used, the proportions in which they are mixed, the mixing process, the placing process, and the conditions in which the work is allowed to set and harden.

Constituents.—Most concretes are mixes of coarse aggregate, fine aggregate and cement. Thus, broken brick or large gravel may be used for the coarse aggregate and sand for the fine, with Portland cement to bind the pieces of coarse and fine aggregate together.

The purpose of the fine aggregate is to fill the spaces between the pieces of coarse aggregate, and the cement should surround each piece of both coarse and fine aggregate. In a special concrete called " No-fines " the fine aggregate is omitted and the concrete is consequently porous with open " cells." This gives certain advantages, including good insulation and absence of condensation, but " No-fines " concrete must be covered with cement rendering to protect it from the weather.

CEMENTS

The principal cements in regular use are :

Portland cement.
Rapid-hardening cement.
Aluminous cement.

Portland Cement.—The raw materials from which Portland cement is made are : chalk and limestone (calcareous material), and clay, mud and shale (argillaceous material), in the approximate proportions of 75 per cent. calcareous material to 25 per cent. argillaceous material. Chalk and clay are generally used, as they are easily worked and processed. The manufacture of cement from these raw materials is carried out with elaborate mechanical plant under strict scientific control.

British Standard Specification No. 12, 1940, specifies certain properties and tests, and when ordering or specifying Portland cement this specification should be quoted. The leading British manufacturers are constantly improving the quality of their cements, so that the properties of a good cement are usually better than called for by B.S.S. No. 12.

There are two grades of Portland cement: *Normal* and *Rapid-hardening*. This gives rise to some confusion, as there is no fundamental difference, and the best normal Portland cements are about the same in rate of hardening as the slowest hardening of the rapid-hardening Portland cements, though the best of the latter are much superior in this respect to the normal cement.

The advantage of a good rapid-hardening cement over the normal cement is that the former sets more quickly and attains greater strength in a shorter period, as shown in the table of properties on page 142. The cost is not much greater, and this may be more than offset by the practical advantages of the work being ready for stripping the shuttering at an earlier date, and the greater strength resulting in economy of material. In the pre-cast concrete products industry the use of rapid-hardening cement speeds up production and allows of greater use of the moulds. In fact, the use of rapid-hardening cement does much to remove the economic disadvantage of having to wait some time for ordinary cement concrete to strengthen sufficiently to allow shuttering to be removed and the concrete to be brought into use.

Portland Blast-furnace Cement.—Blast-furnace slag contains silica, alumina and lime, and by suitable processing it can be made into a cement which in its chief properties is similar to ordinary Portland cement. In practice, the manufacturers of Portland blast-furnace cement mix ordinary Portland cement with the slag cement. This cement is quite as sound and reliable as ordinary Portland cement. It should comply with the conditions of B.S.S. 146 Portland blast-furnace cement.

Aluminous Cement.—This is made from a mixture of bauxite and chalk, the bauxite having a very high alumina content, from which this type of cement takes its name.

The chief advantage of aluminous cement is that it attains its working strength in a much shorter time than either ordinary or rapid-hardening Portland cement. In fact, for some purposes concrete made with aluminous cement is ready for use and loading 10 hours after placing, whereas for ordinary Portland cement at least three days, and for rapid-hardening Portland cement at least two days, are required.

Another advantage of aluminous cement is that it is chemically stable, and is therefore not attacked by other chemicals in the presence of moisture where Portland cement is so attacked. This is due to the fact that Portland cement contains free lime which is chemically unstable, whereas aluminous cement contains free alumina which is, comparatively, stable.

For this reason Portland cement may be attacked by sea-water, neutral sulphates, sulphur fumes, sewage, oils, sugar, beer, etc., to which aluminous cement is immune.

Aluminous cement is also less liable to be attacked by frost than Portland cement, owing to the fact that considerable heat is generated during the setting of aluminous cement.

Setting Time.—It is important to notice the different setting times of

COMPRESSIVE STRENGTH OF CONCRETE AT VARIOUS AGES. (LB. /□")									
MIXTURE BY VOLUME	AGE OF CONCRETE								
	7 DAYS	14 DAYS	21 DAYS	28 DAYS	2 MONTHS	3 MONTHS	4 MONTHS	6 MONTHS	1 YEAR
1:2:4	1000	1500	1800	2000	2500	2800	3000	3200	3300
1:1⅔:3⅓	1150	1700	2100	2300	2900	3300	3500	3700	3600
1:1½:3	1250	1900	2300	2500	3100	3600	3800	4000	4200
1:1:2	1500	2200	2700	3000	3700	4200	4500	4800	5000

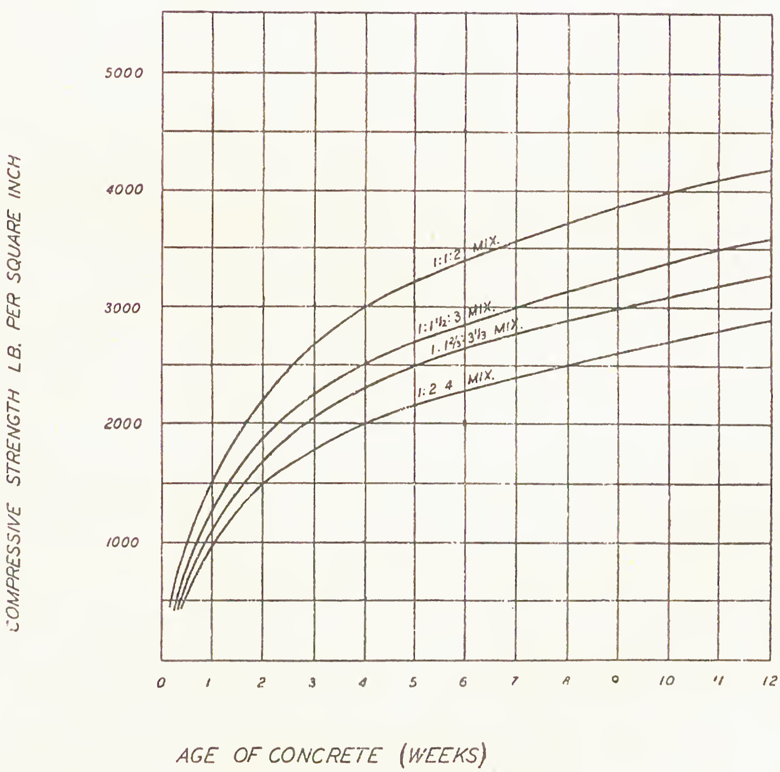


Fig. 144.

the various cements. Setting is divided into two periods: the *initial set* and the *final set*. Concrete must be poured or placed in position before the initial set occurs, and thereafter it cannot be disturbed without destroying much of its strength. The final set of cement takes longer and it does not attain a high proportion of strength until this final set occurs, so shuttering should not be removed until some time after this final set occurs.

Ordinary Portland cement takes 30 minutes or little longer for the initial set, and not more than 10 hours for the final set.

A quick-setting Portland cement may take as little as 5 minutes for the initial set and only 30 minutes for the final set, but this is usually a disadvantage, as 5 minutes is not sufficient time to handle and place the concrete.

Aluminous cement has a much longer initial setting time than Portland cements, but a much shorter final setting time. The advantage of this is, that it gives a longer period during which the wet mixture may stand and a longer period for placing in position, while the rapidity of the final set enables the material to be quickly brought into use. The initial setting time of aluminous cement is from 2 to 3 hours, and the final setting time not more than 2 hours after the initial set.

COMPARATIVE PROPERTIES OF PORTLAND, RAPID-HARDENING AND HIGH-ALUMINA CEMENTS

Ordinary Portland Cement (*B.S.S. No.* 12)	*Rapid-hardening Cement* (*B.S.S. No.* 12)	*High-alumina Cement* (*B.S.S. No.* 915)
Ultimate compressive strength of cubes of cement and sand (1 : 3) by weight		
3 days (72 hours), not less than 1,600 lb. per square inch. 7 days, not less than 2,500 lb. per square inch.	1 day (24 hours), not less than 1,600 lb. per square inch. 3 days (72 hours), not less than 3,500 lb. per square inch.	1 day (24 hours), not less than 6,000 lb. per square inch. 3 days (72 hours), not less than 7,000 lb. per square inch.
Setting time		
Normal-setting Portland cement of either ordinary or rapid-hardening type: Initial setting time not less than 30 minutes. Final setting time not more than 10 hours. Quick-setting cement: Initial setting time not less than 5 minutes. Final setting time not less than 30 minutes.		Initial setting time: Not less than 2 hours nor more than 6 hours. Final setting time. Not more than 2 hours after initial set.
Soundness: Expansion by Le Chatelier test to be not more than:		
10 mm. (0·40 inch) after cooling. 5 mm. after 7 days' aeration	—	1 mm. after cooling.
Fineness Residue on B.S. test sieve No. 170		
Not more than 10 per cent.	Not more than 5 per cent.	Not more than 8 per cent.

White Portland Cement.—A pure white cement, otherwise the same as ordinary Portland cement. As it costs about four times as much as ordinary Portland cement, its use is confined to facing work, usually to a depth of 1 inch. For this purpose it is widely used for both poured concrete and pre-cast products.

Coloured Cements.—Suitable pigments can be mixed, in powder form, with ordinary Portland cement to produce a coloured material, but owing to the difficulty of even distribution and mixing of the colouring matter it is now more convenient to use ready-coloured cements, of which there are several proprietary brands. As these coloured cements are comparatively costly they are used for facing work only.

Coloured Cement-aggregate Mixes.—Better control of colour and better textures are obtainable if, in addition to coloured cement, coloured aggregates are also used. Leighton Buzzard sand is often used instead of ordinary sands for this purpose. Natural building stones and granites may be crushed and used as aggregate. There are several proprietary brands of cement-aggregate mixes, each with a range of colours, and these are widely used for facing working, renderings, and the manufacture of pre-cast tiles and slabs for floors and walls.

COARSE AGGREGATE

As many failures of concrete have occurred through the use of an unsuitable aggregate, great care should be taken in choosing the material. The strength of the aggregate should be adequate for the desired strength of concrete. Thus, it would be a mistake to use soft bricks or natural stone if a strong concrete is required.

The aggregate must be clean and chemically stable. In breeze concrete, for example, trouble may be caused if the aggregate contains any partially burnt coal. And, to give another example, trouble may be caused by using old bricks which are dirty or which have absorbed various chemicals.

The materials commonly used for the coarse aggregate include:

(1) *For Strong Concretes.*—River ballast, pit ballast, broken granite, hard broken brick, hard broken stone.

(2) *For Moderate-strength Concretes.*—Ordinary broken brick, ordinary broken stone, broken (old) concrete.

(3) *For Weak Concretes for Interior Use Only.*—Breeze, clinker, pumice, trass.

The reason why type 3 materials are suitable for interior use only is that they may swell and be disrupted if they are allowed to absorb moisture beyond the normal atmospheric content.

Size of the Aggregate.—This should be suitable for the thickness and purpose of the concrete. For mass concrete foundations the coarse aggregate may be in pieces from 2 inches down to $\frac{1}{4}$ inch; on solid floors laid on the ground from $1\frac{1}{2}$ inches down to $\frac{1}{4}$ inch; for reinforced concrete from $\frac{3}{4}$ inch down to $\frac{1}{4}$ inch. Where the reinforcement leaves very small spaces, the aggregate should have a maximum size much less than $\frac{3}{4}$ inch.

Grading.—To make a dense concrete, it is necessary "to fill all the voids," by which is meant that the space left between the largest pieces of aggregate shall be filled completely by the smaller pieces, including the sand or fine aggregate. In practice this is not easy, but by scientific grading it is possible to fill nearly all the voids and so produce a concrete of maximum density and strength for the materials used.

The scientific grading of aggregate is done by passing the material through a number of sieves, the largest " screen " allowing the maximum specified size of aggregate to pass through, the smallest screen passing the smallest specified aggregate, and the intermediate screens being evenly graded between the two extreme sizes. The aggregate is thus divided into separate heaps, each of a particular screen size. A curve is then plotted which shows the percentage by weight of the total sample which passes through successively decreasing screens.

An easier method of determining the voids in a given coarse aggregate is by immersing a sample in water in a graduated jar or watertight box. First note the volume occupied by the dry sample, then add water sufficient to just cover the sample (taking the water from a graduated vessel so that the quantity can be measured). The percentage of voids can then be calculated as follows :

$$\text{Void per cent.} = 100 \times \frac{\text{Volume of water}}{\text{Volume occupied by dry sample}}.$$

The percentage of voids varies from about 25 to 45. This percentage of sand should then be added to ensure the voids being filled.

While this test determines the percentage of voids, it does nothing to ensure even grading from large to small particles. Some quarries, however, supply properly graded aggregates at a slight extra charge, which is worth while, as properly graded aggregates make stronger concrete.

FINE AGGREGATE

Sand is the usual fine aggregate, although any clean, hard material may be crushed to produce small particles sufficiently fine for the purpose.

There are two important requirements for a fine aggregate : it should be clean and free from chemical or organic impurities, and it should be evenly graded from the largest to the smallest particles. The time-honoured requirement that the sand shall be " sharp "—meaning angular—is not now considered to be of any importance. The sand may be angular or round, but it should be properly graded from the largest to the smallest particles, as already described for coarse aggregate. The test described for finding the percentage of voids can be applied to sand. A good indication of the grading can, however, be more quickly obtained by examining a sample under a powerful magnifying-glass. If it is well graded, the assortment of sizes will be apparent, and if poorly graded the particles will be nearly all of one size.

Pit Sand.—Most sand is excavated from deep sand or sandy gravel beds. Pit sand varies in quality, even in the same pit. In some parts the sand is quite clean and well graded, while in others it is contaminated by impurities washed down from the surface, or is not well graded. Even if the sand is clean where it is found, it may be contaminated by soil from the top falling on it.

Where there is any possibility of contamination the sand should be washed. Most pits have washing plant, and the sand can be bought with a guarantee of cleanness. Simple tests can be made, however, as described later.

River Sand.—This is excavated from river valleys, and provided that the river water is not contaminated by industrial refuse the sand is excellent for use as fine aggregate.

Sea Sand.—This sand contains salt, which is liable to cause efflorescence—the salt being gradually drawn to the surface of the concrete and there appearing as a crystallisation. Even where the concrete is concealed, the salt crystals may cause trouble by spoiling decorations or by exerting pressure in the interface between concrete and plaster or rendering.

WATER

The purpose of mixing the cement and aggregates with water is to produce hydration—a chemical process which results in the cement setting and hardening. It should be clearly understood that the cement is not chemically combined with the aggregates. When it sets it forms a hard film enclosing each piece or particle of aggregate and binding the whole together.

The water must be clean. If it contains any loam or chemical impurities, the setting and hardening of the concrete will be interfered with, resulting in loss of strength. Mains water and clean river water are suitable. Rivers and streams polluted by industrial refuse, sewage, or the humic acid from peaty land should be avoided. Sea-water may result in trouble through efflorescence, although it is otherwise suitable.

Quantity of Water.—As a very wet mix is easier to place in position, especially in small spaces, there is a tendency to use too much water. The quantity of water has an important effect on the strength of the concrete. Just sufficient water to ensure proper hydration and to make the concrete workable is all that is required. An excess of water weakens the concrete, and too little may also weaken it by not allowing complete and consistent hydration.

An excess of water weakens the concrete by "washing" away the cement from some of the aggregate, the heavier pieces tending to sink. But the quantity of water must vary owing to the fact that while a fairly stiff mix can be easily poured into large spaces, such as foundations, a more plastic mix is required to enable the concrete to be worked into small spaces such as between reinforcement bars which may be only 1 inch apart.

It is authoritatively suggested that a safe rule for calculating the quantity of water is to take 28 per cent. by weight of the cement, and add 4 per cent. by weight of the sand and ballast. This gives the weight of water required to give a good working mix when the sand and ballast are dry and of non-absorbent materials. If the materials are absorbent, a sample of known volume should be taken and weighed in the dry state.

Then saturate the sample with water and weigh again. The difference in weight is the weight of water absorbed, and this should be added to the quantity of water, as found above, required for mixing the concrete.

As an example: a 1 : 2 : 4 mix (1 part Portland cement, 2 parts sand, 4 parts coarse aggregate) requires 112 lb. cement, 224 lb. sand, and 448 lb. ballast, and the quantity of water calculated by the foregoing rule should be: 28 per cent. of weight of cement = 31 lb. water; 4 per cent. of weight of sand and ballast = 27 lb. water. Total weight of water required = 58 lb. If the aggregates are absorbent, additional water is necessary to allow for absorption, as already described.

It is found that the smaller the proportion of cement to aggregate, the smaller the quantity of water required for a given quantity of aggregate.

STORAGE OF CEMENT

As Portland cement readily absorbs moisture, and its strength is greatly reduced thereby, it must be stored in a dry position. A dry, well-ventilated shed with a wood floor raised above the ground is best. But in an unheated shed the cement will absorb moisture from the atmosphere if kept there for a lengthy period, and such absorption is greater in the case of modern finely ground cements. The safe maximum absorption is about 2 per cent. Any further absorption reduces the strength and retards hardening.

Cement is now delivered in paper bags, which give better protection against atmospheric moisture than jute bags. On delivery the bags should be placed on a dry floor or platform and covered with a tarpaulin, or, better still, placed in a dry shed. Stored in a shed it will not suffer serious deterioration for two or three months in reasonably dry weather, but it is advisable to use it as soon as possible after delivery from the works.

If cement must be stored for many months, it should be emptied into large bins. After some months a hard crust will form on top. When the cement is to be used this crust should be removed.

For export, airtight steel drums are used, and in these the cement will keep in good condition indefinitely.

SITE TESTS

There are certain tests for cement, sand and coarse aggregate which can be easily carried out on the site. The great importance of sound materials has already been pointed out, and even for a small job it is advisable to carry out site tests.

Testing Portland Cement.—If the cement is in good condition, it should be warm. Open the bag or bin and plunge the bare arm into the middle of the cement. If the cement is slightly warm (about normal blood heat or little less), it is probably sound. If it is cold, there is something wrong, and the makers should be informed if it has been recently delivered and properly stored.

If the cement contains many hard lumps, it is a clear indication that an excessive amount of moisture has been absorbed and the strength ruined. A few very small lumps are not necessarily an indication of spoilt cement, but the cement should be sieved to remove the lumps.

A rough test for setting-time consists of mixing a few samples of cement with three parts sand and sufficient water to make a stiff mix. Drop the samples from a height of 30 inches at intervals between 10 and 30 minutes, the intervals being closer between the last few samples. When the initial set has occurred (it should occur after about 30 minutes with normal Portland cement), the samples will only be slightly flattened by the fall, and testing further samples will reveal very little difference.

A better test than the above may be carried out as follows: Mix 1 lb. of cement with sufficient water to make a stiff paste, and with a trowel mould it into a "pat" on a sheet of glass or slate. The pat should be about 3 inches square and 1 inch thick. Leave it in a moderately warm place under cover for 20 hours and then test with the thumbnail. The cement should be hard enough to resist moderate pressure and the thumbnail should make no impression. If after 24 hours any impression can be made by this means, it is probable that the hardening property has seriously deteriorated. After 48 hours take hold of the pat in both hands and try to break it. If the cement is sound, this should require considerable effort.

The cement pat can also be used as a rough test for soundness and freedom from excessive expansion. Boil the pat in water for three hours. If it does not soften or crack, the cement is sound.

Testing Sand.—A rough test for cleanness is to rub a sample of sand on the palm of the hand. Any dirt or loam will adhere to the hand.

A better test is to place a sample of the sand in a glass, filling about half the glass, and then add water to cover the sand. Any solid impurities, such as loam, vegetable matter or peat, will be easily seen after the contents have been stirred and then allowed to settle. If the impurities are considerable, there will be a distinct line of demarcation between sand and impurities. Only the slightest visible trace of foreign matter should be tolerated in a sand to be used for concrete of any importance, and in no case should the foreign matter exceed 5 per cent. by volume.

A valuable test for cleanness of sand is to make up a test cube of cement and sand, mixing 1 part cement to 2 parts sand by weight with sufficient water to make a stiff mix. It is assumed that cement of proven soundness is used. Mould the mix into a cube on a piece of glass. Leave it for 24 hours in a moderately warm atmosphere and it should then be fairly hard. If it is not, leave it for a further 12 hours. If it is still not hard, and it is known that the cement has a normal hardening rate, the sand may be suspected of impurity. If after 48 hours the cube is still not hard, there is probably serious impurity in the sand.

Testing Coarse Aggregate.—Visual inspection with the aid of a magnifying-glass will show whether the aggregate is dense or very porous, dusty or dirty. By breaking with a hammer, a rough idea can be formed of the strength.

Testing Breeze and Clinker.—These aggregates sometimes cause trouble owing to the presence of free chemicals or partially burnt coal, causing considerable expansion.

A pat test should be carried out in the following manner: Prepare a mix of 1 part ordinary Portland cement and 1 part fine white plaster of Paris. Then prepare a dry mix of this cement-plaster and a sample of the breeze or clinker aggregate in the proportion of 1 part of the cement-plaster to 3 parts of the aggregate by volume. The aggregate must first be ground to a powder to pass a No. 76 mesh sieve.

Now mix with water to a normal plastic condition, roll into a lump, and place in the centre of a glass plate about 4×4 inches. The wet mix will flow towards the edges of the plate and should be shaped with a knife to form a pat 3 inches in diameter, curving the top so that it is $\frac{1}{2}$ inch thick in the middle and of practically no thickness at the perimeter. Complete the pat within 5 minutes of preparing the wet mix. Two or three pats can be made to make the test more satisfactory.

When the pats are made place them at once in a moist atmosphere, which may best be done by placing them on a wire tray over a bucket of water. There they should be left for three to four hours, and then immersed in water and left.

The pats should not be disturbed or removed from the water, but they should be inspected every day. If the breeze or clinker is sound, the pats will not lift from the glass nor develop fine cracks. If the aggregate is unsound, the pats will lift and develop fine radial cracks. If no such changes appear within four days, the aggregate is probably sound; if changes appear after four days, slight instability of the aggregate is indicated, but it may be used for ordinary purposes where the concrete will not be exposed to moisture. If changes appear in less than four days, the aggregate should be rejected. Where a large quantity of aggregate is involved several tests should be made from each delivery load.

The Slump Test.—This is a test for correct quantity of water in a concrete wet mix. It requires a metal mould 12 inches high, 8 inches diameter at the base and 4 inches at the top. The mould should be filled with a sample of the wet concrete as mixed on the job. Filling is done in layers of 3 inches each, puddling each layer with 25 strokes of a $\frac{5}{8}$-inch steel rod 2 feet long, bullet-pointed at the lower end. When filled the top should be struck off level so that the mould is completely filled. The mould is then removed by raising vertically, immediately after filling.

The wet concrete will then slump, and the amount of this slump or settlement should be measured in inches (see Fig. 145).

For fairly stiff concrete to be laid in plain masses, as in foundations, a slump of 2 inches or little more is desirable. For concrete to be placed in small spaces, and thus requiring a more plastic mix, the slump should be 3 inches to 4 inches, and where the spaces are very small, as in concrete with closely spaced reinforcement, the slump may be 5 inches to 6 inches. But 6 inches should be regarded as the maximum, and if possible it should be kept below this. The weakening effect of too much water has already been described. Hence the importance of the slump test.

Cements other than Portland.—These include natural cement, such as Medina and Roman, and foreign cements, also Puzzuolana.

Of the natural cements ***Medina*** is found in the River Medina, in the Isle of Wight. It is similar to Roman in appearance but slightly lighter. The clay from which the cement is made is called Septaria. This is ground finely, and produces a quick-setting cement used particularly in situations in which the work has to be constructed between the falling and rising of the tides.

Roman Cement is formed from London clay, which is burnt at a very low temperature, and from clay found in the shale beds of the lias formation. This also is a very rapid-setting cement, requiring only about 20 minutes after mixing, and like the last, was also used for constructional work in tidal areas, until the introduction of the quick-setting Portland cements.

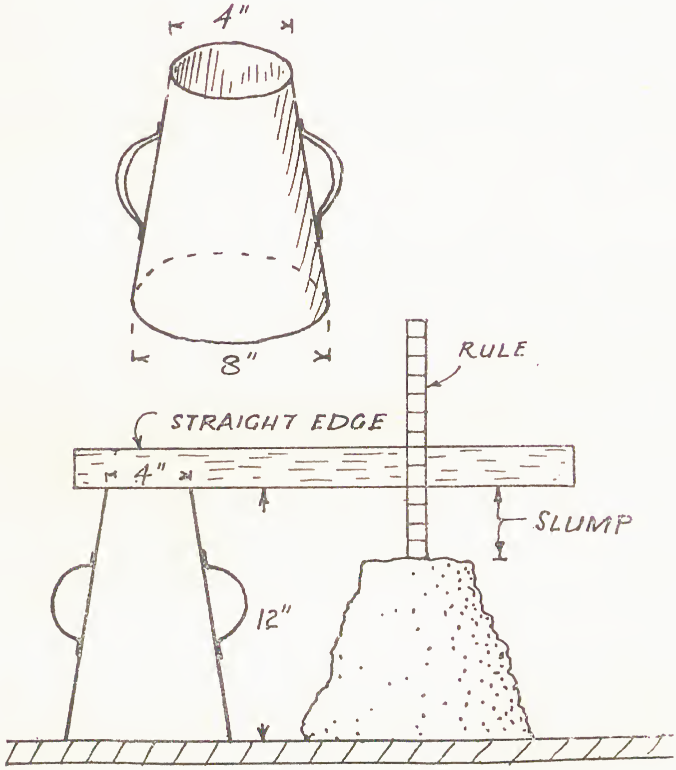


Fig. 145.—Slump test.

Foreign Cement.—In accepting any foreign cements, it is advisable to require that a test should be made to ensure that they are not adulterated, and that they comply with the standard specification.

Puzzuolana.—This is a natural volcanic substance found at Puzzuola, near Naples, which, mixed with lime, produces a hydraulic cement. This was used by Smeaton in the construction of the Eddystone Lighthouse, where it was necessary to use a mortar or cement capable of withstanding the influence of the sea. It was also required that the cement used should have a strengthened adhesive value to withstand the overturning force of wind and waves. This is supposed to have been the cement used by the Romans, and is said to be inferior to that manufactured as Portland cement. However, as there are buildings now, though in ruins, still standing erected by the Romans in which the mortar used has defied the elements longer than the stone and brick which it held together, it would seem that a very powerful cement is to be formed by mixing in with Portland cement some such material as Puzzuolana. The old mortars had in them a quantity of small particles of a very hard nature, forming a kind of concrete, and very satisfactory mortar is to be made by grinding old well-burnt bricks and tiles and adding this to lime instead of sand, which forms an artificial Puzzuolana.

Puzzuolana Mortars.—Whereas in the standard mix used in all earlier tests the mortar was composed of 1 part of hydrated lime, 1 of Puzzuolana, and 6 of sand by weight, this mixture was found to contain an excessive amount of lime, and that at least one-third of the lime was not combined with the Puzzuolana after 2 years' storage in water. Consequently, a larger proportion of Puzzuolana was indicated.

Staining and Efflorescence.—Tests have been carried out by the Building Research Board, comparing the effects of the staining by lime and cement mortars, and their mixtures with Puzzuolanas. The tests also included notes on the amount of efflorescence produced by this. The conclusions arrived at were that ordinary burnt clay or spent shale Puzzuolanas do not reduce the staining caused by the cement mortars. White Portland cement produced less staining than grey, and a white burnt China-clay Puzzuolana was better than a white cement. But the best results of all in these respects was given by a good hydrated fat lime.

CHAPTER 8

CONCRETE MIXING AND APPLICATION

CONCRETE is often specified in certain proportions of cement, sand, and coarse aggregate, as measured by volume. Thus, a 1 : 2 : 4 mix consists of one part Portland cement, two parts sand, and four parts coarse aggregate. The maximum size of the coarse aggregate is also usually specified.

As cement in bulk varies in density with the comparative closeness or looseness of the cement, it is now usual to specify the cement by weight and the sand and coarse aggregate by volume. Thus, a 1 : 2 : 4 mix is better specified as 1 cwt. Portland cement, 2½ cubic feet sand, 5 cubic feet coarse aggregate.

Proportions.—The greater the amount of cement in a mix the stronger the concrete, and, of course, the higher the cost. The strength should be suitable for the purpose of the concrete, and under some conditions an excessively strong concrete may be a disadvantage. For example, in walls a very strong concrete may show marked crazing and fine cracks, owing to excessive expansion and contraction, and the dense material may give rise to condensation.

The following are the usual proportions for various purposes, and the proportions are such that with well-graded aggregates practically all the voids will be filled.

Proportions by Volume.	*Cement*	*Sand.*	*Coarse Aggregate.*	*Min. ultimate strength (crushing) within 28 days.*
1 : 1 : 2	1 cwt.	1¼ cubic feet	2½ cubic feet	2,925 lb. per sq. in.
1 : 1½ : 3	1 cwt	1⅞ cubic feet	3¾ cubic feet	2,550 lb. per sq. in.
1 : 2 : 4	1 cwt.	2½ cubic feet	5 cubic feet	2,250 lb. per sq. in.

All the above can be used for reinforced concrete. It will be seen that the differences in strength are not very great. Notice also that in each case the coarse aggregate is twice the amount of the fine aggregate. This gives the best result in filling the voids between the coarse aggregate with sand.

The 1 : 2 : 4 mix is widely used for a variety of purposes in both plain and reinforced concrete as it is economical and has good strength. It is the minimum strength mix allowed for reinforced concrete.

Weaker concretes than the above mixes are used in foundations, over-site concrete, and for filling. In such concrete the proportion of cement may not be lower than in a 1 : 2 : 4 mix, but instead of using definite proportions of fine and coarse aggregate and selecting strong aggregates, a material such as old brick may be broken up and used in the proportion of 1 cement to $7\frac{1}{2}$ or 10 of aggregate, no separate fine aggregate being added.

For filling to make up levels under solid floors the proportions are usually 1 : $12\frac{1}{2}$ or 1 : 15.

Regulations governing plain and reinforced concrete are given in Chapter 10 of this volume.

Materials Required.—In calculating the volume of materials required to make 1 cubic yard of concrete we must remember that the volume of wet concrete is about 35 per cent. less than the volume of the dry mix.

Thus, although a cubic yard equals 27 cubic feet, 41·5 cubic feet of dry materials will be required to make 1 cubic yard (27 cubic feet) of concrete. We now have to find the volume of each material. In the case of a 1 : 2 : 4 concrete this is calculated as follows:

Cement $\frac{41{\cdot}5 \times 1}{7} = 5{\cdot}9$ cubic feet = 534 lb.

Sand $\frac{41{\cdot}5 \times 2}{7} = 11{\cdot}9$ cubic feet

Coarse aggregate $\frac{41{\cdot}5 \times 4}{7} = 23{\cdot}7$ cubic feet.

By the same method the volume of each constituent material may be found for any given proportions. This is a useful calculation, especially for estimating and pricing, but it is better to use the method of specifying the aggregates by volume to be mixed with 1 cwt. of cement.

The Measuring Box.—It is advisable to use a double measuring box. An example is shown in Fig. 146. This is a bottomless box with two compartments, one for the fine aggregate and one for the coarse. The size of the compartments must be selected to give correct proportions. In the case of a 1 : 2 : 4 mix, the coarse aggregate being twice the volume of the fine, the larger compartment must have twice the capacity

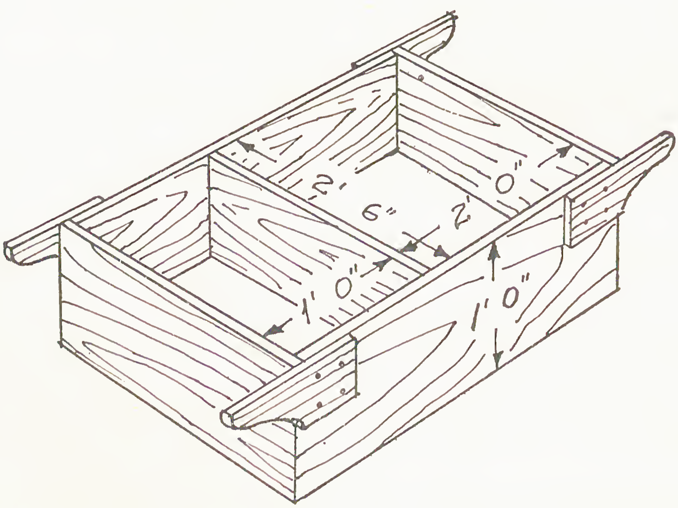


Fig. 146.—Double measuring box for sand and coarse aggregate. A bottomless box for use on mixing platform. Smaller compartment holds $2\frac{1}{2}$ cubic feet and larger 5 cubic feet. One filling of compartments, plus 1 cwt. cement, makes a 1 : 2 : 4 mix concrete.

of the smaller. The box in Fig. 146 has been designed to hold $2\frac{1}{2}$ cubic feet of sand and 5 cubic feet of coarse aggregate. These quantities are correct for adding to 1 cwt. of cement to make a 1 : 2 : 4 mix.

The measuring box should be placed on a boarded or paved platform, the dry materials shovelled in and levelled off at the top; the box is then lifted, and the cement added. The three dry ingredients are then mixed preparatory to adding water.

For larger batches the measuring box should have double the capacity of that shown in Fig. 146. Twice the weight of cement (2 cwts.) must then be added to make a 1 : 2 : 4 mix.

Dry Mixing.—The three materials must be thoroughly mixed in the dry state. This is done by turning them over with the shovel until the cement is evenly mixed with the aggregates and the dry mix is of an even colour.

Wet Mixing.—The dry mix is then watered, using a hose with a rose fitting, or a watering can with a rose. Care should be taken to use the correct amount of water as already described in Chapter 7. The water should be sprinkled gently and gradually while the mixture is being turned over with the shovel. A watering can is preferable to a hose, as it gives a definite measure of the amount of water used. Using a hose, it is very easy to add too much water, which will result in loss of strength in the concrete.

Thorough mixing, both dry and wet, is essential if the concrete is to attain full strength and not to develop defects. Care should also be taken to prevent earth or vegetable matter being mixed with the concrete, and in wet weather the heap should be protected from heavy rain.

Placing Concrete.—The concrete should be placed in position as soon as possible after wet mixing. This must be done before the initial set occurs, which with ordinary Portland cement is 30 minutes. On no account should the concrete be disturbed after this period, and any concrete not placed within this period should be rejected or used for filling up the ground.

The quantity mixed at one operation should obviously not be more than can be placed before the initial set occurs. With quick-setting cements this needs careful supervision.

Mixing is performed both by hand and by machinery; and with reference to the quantity of water required, it may be helpful to note here that the machines now on the market for mixing concrete are mostly supplied with automatic water supply tanks, by means of which the correct quantity of water is automatically measured.

MIXING BY HAND

The first requisite is a smooth level surface on which to mix the materials; this may be composed of boards, which should be tongued and grooved or jointed so closely that the water will not pass through the joints, or on some jobs steel plates are used. In either case there should be a raised edging to prevent the water from running off and carrying the cement with it. In conjunction with this mixing platform two gauge boxes are required, one for the aggregate and one for the cement, of the required internal dimensions to give the proper proportions. These mixing boxes consist of four sides without top or bottom, and two of the sides are extended at each end, being cut down to form handles. The aggregate mixing box being placed centrally upon the platform, it is then filled with aggregate, being levelled off at the top, and the cement box is then placed on top of the aggregate and likewise filled. Both boxes are then lifted off. The materials are then turned over three times dry ; the object to be obtained in this dry turning over is that the cement, sand, and coarse aggregate shall be as integrally mixed as is possible. Though much is said of the necessity for thorough mixing after the water has been applied, yet it is probable that the final condition of the concrete depends more upon this initial dry mixing than on any other operation in its manufacture. The mixture is then watered through a hose, and it should be noted that it is easier to obtain the proper amount of water if it be applied from a watering can of known cubic contents than if a hose be used, the last being a very frequent cause of over-watering. As the mixture is being wetted it should be again turned over twice, or better still three times.

When mixed the concrete must be deposited in the place where it is required at once, and as the chemical action begins immediately the cement is wetted, it is better that a small quantity should be mixed at a time.

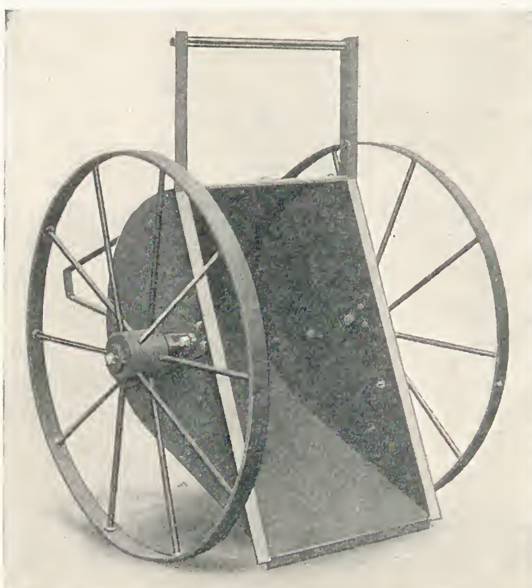


Fig. 147.—Tip cart.

Barrows.—For the purpose of depositing the concrete, iron barrows are the best and the most economical. These are specially shaped to afford ready depositing, and hold only a small amount of concrete, which gives the tamping operation a sufficient time to be properly performed in between the deposits.

Hand Tip Carts are also provided, having a single container of 6 cubic feet, and being on two wheels are easier to handle than barrows, but there are tip carts now which are also provided with divisions, splitting up the interior into compartments of the proper cubic capacity to give the right proportions of aggregate and cement, and these consequently also form a substitute for the mixing boxes described above.

Tip carts for carrying the concrete from the machine to the place where it is to be deposited are also supplied of about 7 cubic feet capacity. These are carried on two wheels, and one compartment is constructed of steel plate welded at the corner and having a steel angle round the top edge. A point worthy of notice in connection with these tip carts is that the wheels are as much as 3 feet 6 inches in diameter, which enables them to be more easily moved when loaded. The rims of the wheels are constructed of rolled steel flats and the spokes of mild steel bar. The front is sloped out at an angle suitable to afford a very ready deposit of the concrete mix without any remaining behind.

MIXING BY MACHINERY

There is a great variety of machines for mixing concrete, though the principle underlying these is all more or less the same. They consist of a metal container called the Drum, which revolves; and the mix, when placed inside this, is turned over by some form of blade or other agitator in the interior of the drum. But whatever type be chosen, the best will be found to be the simplest and the one in which the working parts are protected as much as is possible from the small grit in the mix. Where such protection is not provided, the wearing on the teeth of any gearing is very considerable. These mixers range from small machines having an output of about 24 cubic yards a day, to large mixers having a capacity of 77 cubic yards per day. There are mixers made for special purposes, one type being fitted with four road wheels, another mounted on a gantry, fitted with a handrail, platform, etc., by which is afforded the possibility of discharging concrete at a height above the ground level, and at the same time filling the skip at or even below ground level. By extending the runway to the required length the skip may be filled at any depth below the ground level. The drum discharges into an adjustable chute, which can be

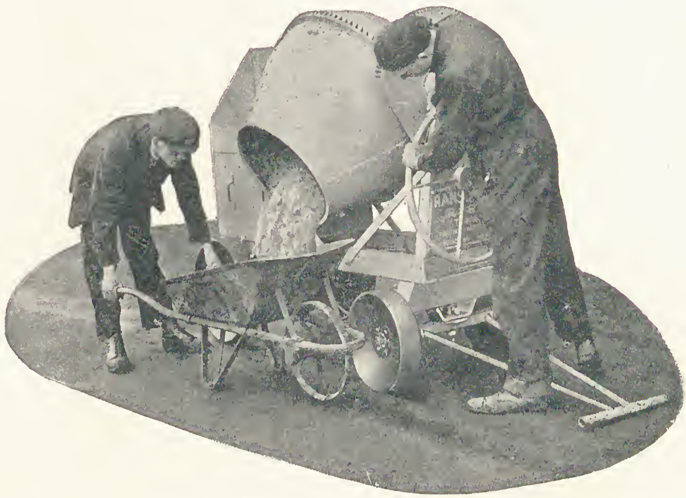


Fig. 148.—Discharging from tilting drum mixer. (*Ransomes & Rapier, Ltd.*)

arranged to suit any type of truck, barrow, or tip wagon, into which the mix is to be emptied. For the operator working the machine there is a platform reached by a rigid ladder. Another type of mixer is equipped with a self-contained barrow hoist. To operate this there is an inde-

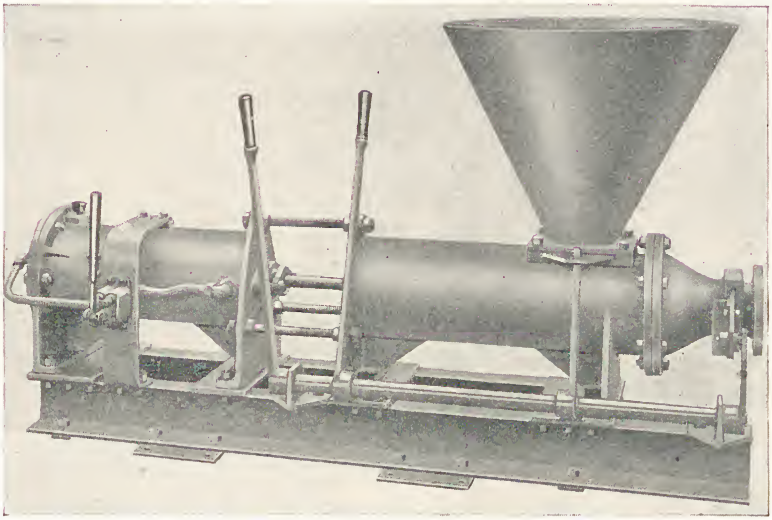


Fig. 149.—Concrete pump for pumping concrete up to ¾-inch aggregate behind forms for tunnel lining. Operated by compressed air. (*Ransomes & Rapier, Ltd.*)

pendent clutch, brake, and single lever control. This hoist is capable of lifting loads of 6 cwts. at a speed of 60 feet per minute.

Types.—Machine mixers are of the following types :

1. Tilting drum without loading hopper.
2. Tilting drum with loading hopper.
3. Non-tilting drum with loading hopper and discharge chute.
4. Roller pan with discharge gate.

1. *Tilting Drum without loading hopper.*—The smaller concrete mixers are of this type. Most firms make two or three sizes. The following is a typical range :

Batch capacity. *Unmixed.*	*Mixed.*	*Output per 8-hour day.*	*Engine H.P.*	*Approx. weight.*
5 cubic feet	3½ cubic feet	27 cubic yards	1½	10 cwts.
6 cubic feet	4 cubic feet	47 cubic yards	3½	22 cwts.
7 cubic feet	5 cubic feet	40 cubic yards	1¾	14 cwts.

A petrol engine is normally fitted, but a paraffin engine, electric motor, belt or hand drive can be fitted to special order.

The mixing drum revolves on a centre post supported in a cradle bracket. The tilting gear is operated by a large hand wheel. The

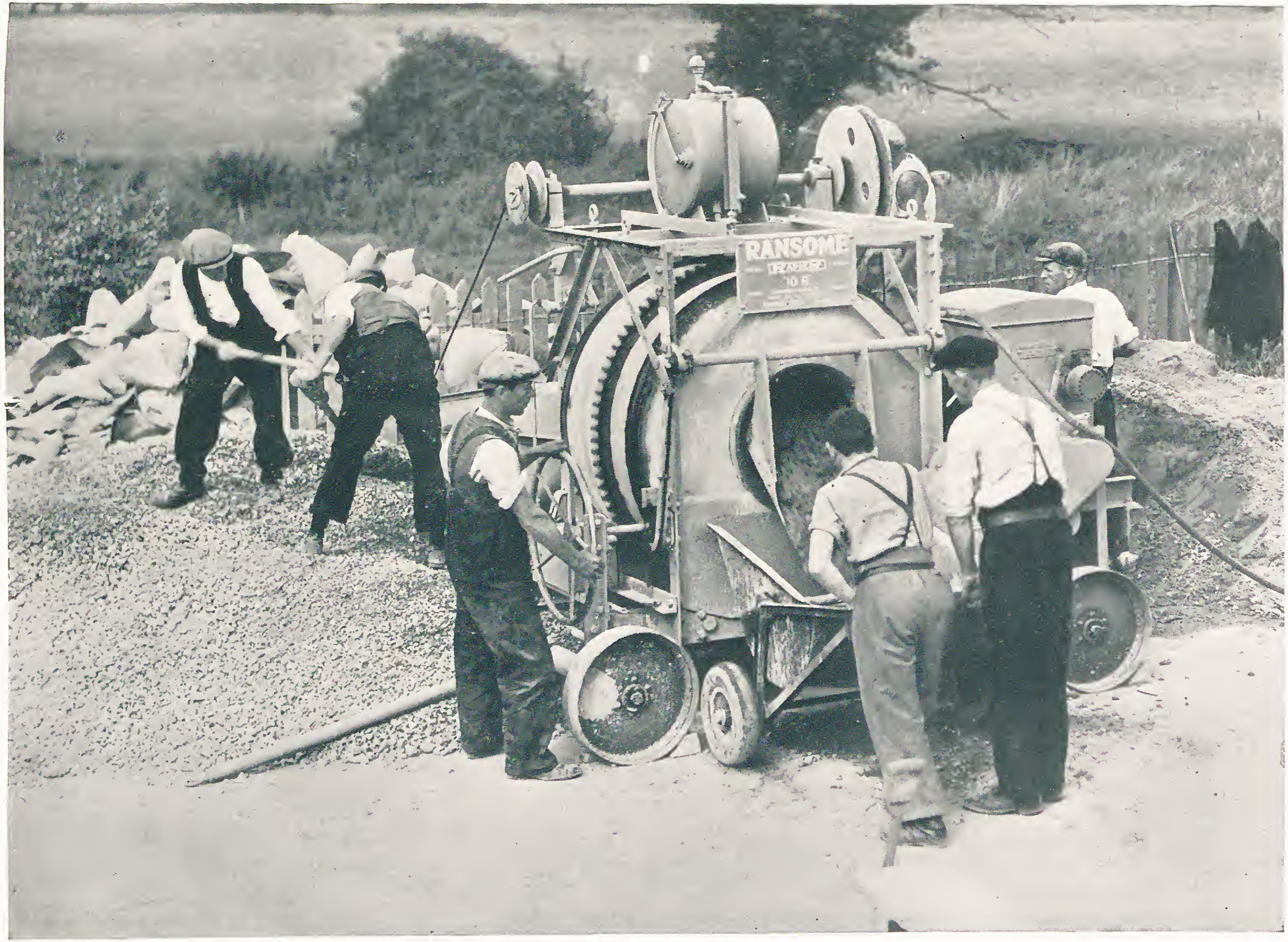


Fig. 150.—ROTARY DRUM CONCRETE MIXER, DIESEL ENGINE DRIVE.

FIG. 151.—JAEGER 2½-CUBIC-YARD TRUCK MIXER ON MONARCH CHASSIS. DRY MATERIALS ARE LOADED AT WORKS AND CONCRETE MIXED DURING JOURNEY.

drum can be filled and discharged on both sides of the machine, and an automatic lock is fitted for the mixing positions of the drum.

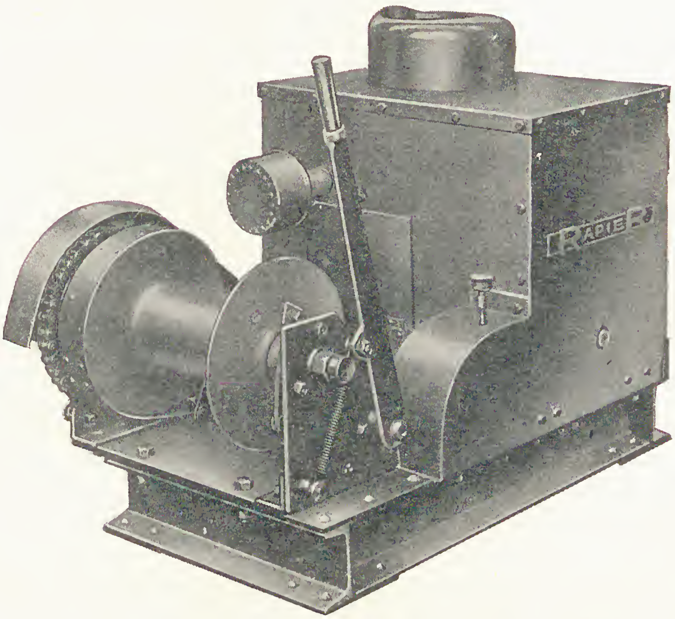


Fig. 152.—Motor and winch unit for use with platform hoist, to lift 10 cwts. Engine 5-h.p. petrol. (*Ransomes & Rapier, Ltd.*)

An automatic water tank can be fitted as an extra.

The normal chassis has four steel wheels and is fitted with a drawbar, but rubber-tyre road wheels can be fitted.

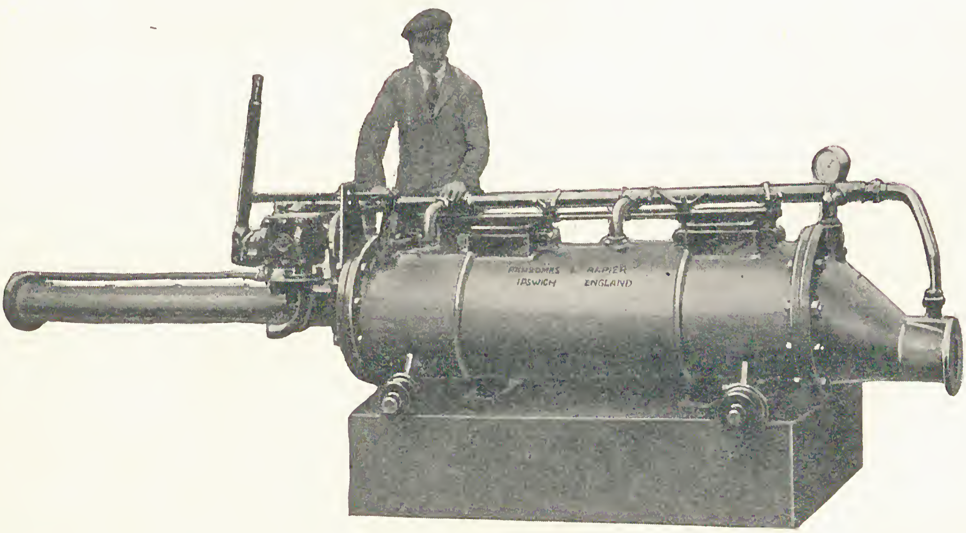


Fig. 153.—Concrete placer, air operated ; concrete blown through piping distance over 100 feet. Deals with batch of 10 cubic feet concrete per hour. Maximum size of aggregate, $1\frac{1}{2}$ inches. (*Ransomes & Rapier, Ltd*)

2. *Tilting Drum with loading hopper.*—These are heavier machines, the essential difference between this and Type 1 being the loading hopper or skip which is more convenient for loading. In the loading position the skip is low, and when the dry mix has been loaded the skip is hoisted and the contents are discharged by gravity into the drum.

This type of mixer is fitted with a siphonic water tank which accurately measures the amount of water and discharges it through a nozzle into the drum. The tank is fitted with a graduated scale and a quantity adjuster.

The following is a typical range of machines of the tilting drum type:

Batch capacity.		*Output per 8-hour day.*	*Engine H.P.*	*Approx. weight.*
Unmixed.	*Mixed.*			
6 cubic feet	4 cubic feet	47 cubic yards	$3\frac{1}{2}$	22 cwts.
7 cubic feet	5 cubic feet	60 cubic yards	$3\frac{3}{4}$	27 cwts.
10 cubic feet	7 cubic feet	77 cubic yards	5	35 cwts.
14 cubic feet	10 cubic feet	150 cubic yards	7	51 cwts.

Petrol, paraffin, or diesel engines can be fitted and the machine can also be obtained with electric motor or belt drive. Steel wheels, solid rubber, or pneumatic tyres.

3. *Non-tilting Drum.*—This type differs from 1 and 2 in having a non-tilting drum which has a loading hopper on one side and a discharge chute on the other. An automatic siphon tank is fitted for supplying the correct quantity of mixing water. A variety of fittings and wheels are available to suit special conditions.

The following is a typical range of machines of the non-tilting drum type:

Batch capacity.		*Output per 8-hour day.*	*Engine H.P.*	*Approx. weight.*
Unmixed.	*Mixed.*			
7 cubic feet	5 cubic feet	65 cubic yards	5	28 cwts.
10 cubic feet	7 cubic feet	83 cubic yards	6	37 cwts.
14 cubic feet	10 cubic feet	107 cubic yards	9	44 cwts.
20 cubic feet	14 cubic feet	140 cubic yards	12	65 cwts.

A special type is also made for large batch capacity as follows:

60 cubic feet	42 cubic feet	335 cubic yards	25	230 cwts.
80 cubic feet	60 cubic feet	480 cubic yards	40	300 cwts.

Works Mixing.—The practice of mixing concrete at the works or a convenient depot and delivering in trucks is convenient in some cases. For this purpose the mixers may be mounted on platforms or gantries to facilitate discharging into the trucks.

Truck mixers are sometimes used. The mixer is permanently mounted on a motor truck. The concrete can be mixed *en route* and on reaching the site discharged in the exact position required. Three sizes are made: $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ cubic yards wet mix. At the central depot a batching plant discharges the correct quantities of fine and coarse aggregate into the truck mixer and the operation takes only a few minutes.

Fig. 154.—CONCRETE MIXER WITH SWINGING BOOM AND TRAVELLING HOPPER FOR ROAD-MAKING.

Fig. 155 (*Below*).—CONCRETE VIBRATOR. BY USING A VIBRATOR THE CONCRETE IS BROUGHT TO MAXIMUM DENSITY, AND RATHER STIFF MIXES CAN BE USED.

(Ransomes & Rapier, Ltd.)

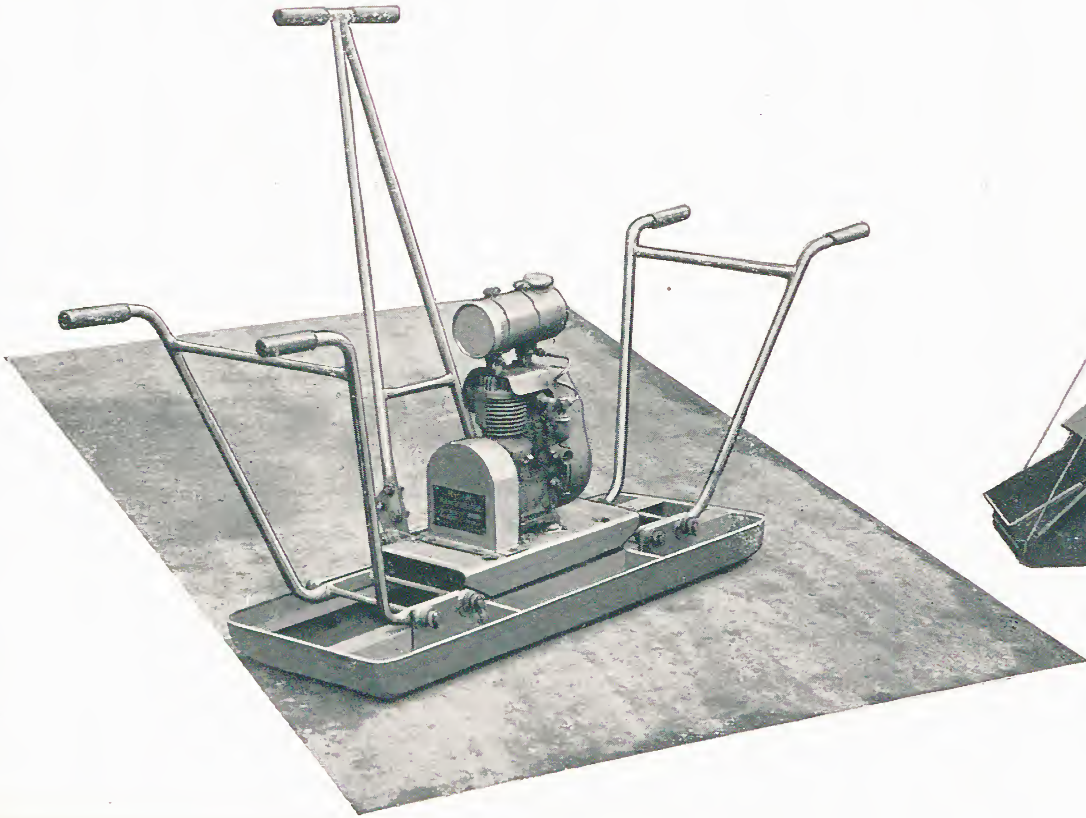


Fig. 156 (*Above*).—PAN MIXER MOUNTED ON HIGH GANTRY AND FITTED WITH FEEDING SKIP AND ELECTRIC DRIVE.

(Ransomes & Rapier, Ltd.)

4. *Pan Mixers.*—In this type the mixing pan is fixed and the mixing is done by steel blades arranged to give a ploughing action and heavy iron rollers mounted on an adjustable spring-loaded axle. This type crushes as well as mixes and will crush broken bricks down to small aggregate. The type is also largely used for mixing mortar.

A popular pan mixer has the following performance :

Approximate output per 8-hour day.

Mortar.	*Clinker Concrete.*	*Ash Mortar.*
Cement and sand or Cement and lime.	For slab or concrete products.	Medium or light weight.
25 tons.	18 tons.	15 tons.

Power is provided for this mixer by a 5-h.p. petrol engine, or by a paraffin or diesel engine. It can also be arranged for electric motor or belt drive. The weight is 35 cwts.

CONCRETE DISTRIBUTING PLANTS

For work on large jobs, where it is required to distribute the concrete over wide areas and to several parts of the site, the concrete is carried

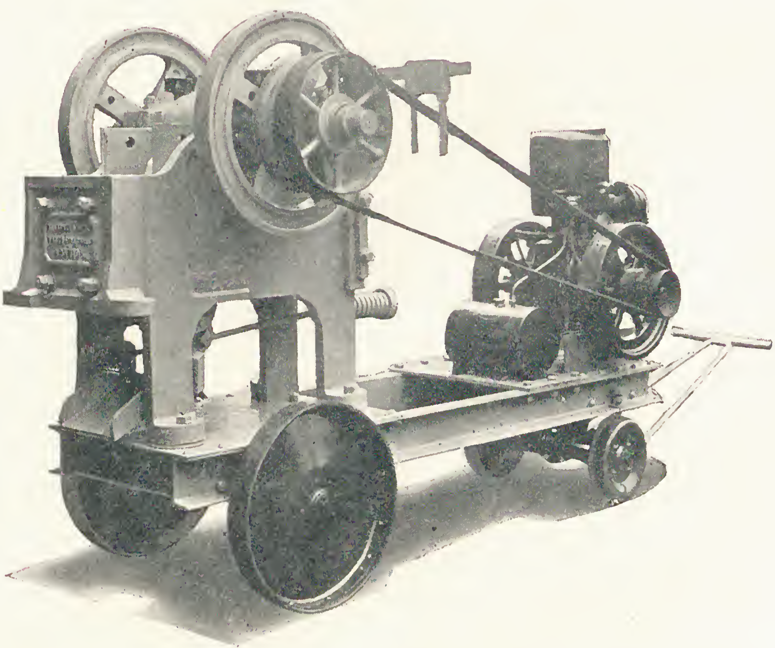


Fig. 157.—Brick and aggregate crusher. (*Ransomes & Rapier, Ltd.*)

up towers formed of steel framework to any height required, at which it may be deposited in chutes leading to the points required. After mixing, which is carried out on the ground level, the concrete is deposited into a skip, and when hoisted to the required height it is automatically tipped from a skip into the chutes. A particular point, worthy of note, is that these chutes are adjustable, and can be directed to any point desired, but the chutes and conveyors are likely to present one drawback ; for it should be remembered that the initial set of concrete from the time of mixing takes place within 30 minutes. Consequently, there will be a danger of concrete sticking to the sides of the chute unless these are kept wet or the mix made a good deal wetter than it is actually required to be. Especially is this the case in situations where the work is exposed to too great heat from the sun or winds that are too drying.

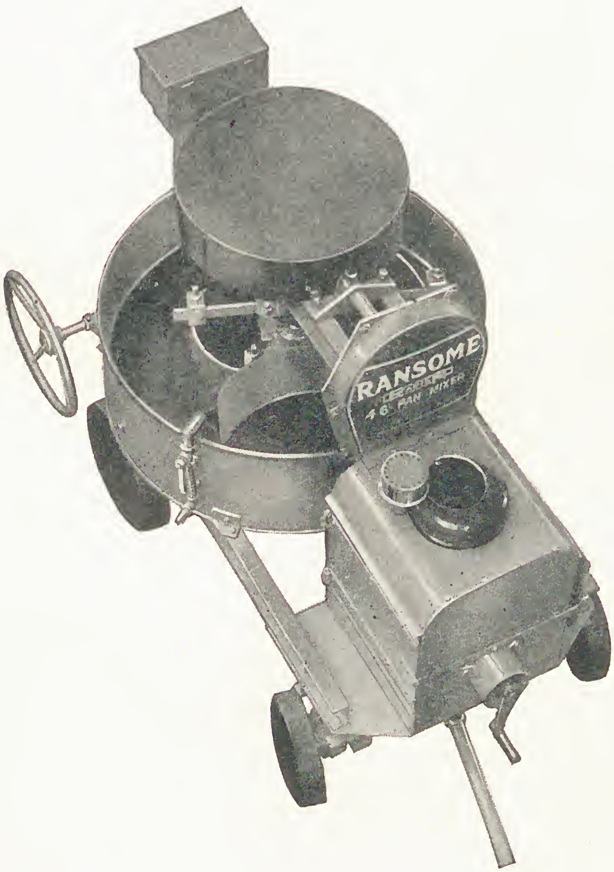


Fig. 158.—Roller pan mixer, for mixing mortar and fine-aggregate concrete, also crushing broken bricks.

Output : Mortar, cement, or lime . 25 tons 8-hour day.
Mortar, ash . . . 15 tons 8-hour day.
Concrete, clinker . . . 18 tons 8-hour day.
Engine : 5-h.p. petrol, or $3\frac{1}{2}$-h.p. for light work such as sand-lime mixing. (*Ransomes & Rapier, Ltd.*)

Compressed-air plant is now used both for distributing concrete and placing it. The concrete is blown through piping which may be up to 6 inches in diameter. Concrete has been conveyed by this means to distances of over 100 feet, dealing with 10 cubic feet of concrete per hour.

Concrete pumps are useful for placing concrete in awkward positions, such as behind forms for tunnel lining, and a grouting pump has been found of great use in repairs to bridges, tunnels, and other work not directly accessible by ordinary means.

Stone Breakers.—For use in reducing coarse aggregate, *crushers* are supplied, a 20 × 12-inch mouth machine having an output of from 11 to 14 tons per hour. The body of the machine is a solid semi-steel casting about 20 per cent. stronger than cast iron. The jaw stock is of carefully annealed cast steel, bored out to take the shaft. The bearings may be either white anti-friction metal or gunmetal to suit different conditions, though white-metal bearings are fitted to the standard machine. A forced feed lubrication is fitted, though a large grease reservoir is provided which is usually found efficient without resorting to

FIG. 159.—MAST HOIST IN USE ON BUILDING WITH WALLS OF PRE-CAST CONCRETE BLOCKS.

(Ransomes & Rapier, Ltd.)

the forced feed. The wearing parts, such as jaws, side cheeks, and toggle liners, are of manganese steel, the jaws being reversible end to end.

Where it is required to feed into a machine larger-sized stone, and the chippings desired are to be reduced to about $\frac{3}{4}$ inch to $\frac{1}{2}$ inch, a machine known as a *Granulator* is supplied of materially different design from the stone breaker. The size of the mouth is from 10 × 4 inches to 24 × 7 inches, and the approximate quantity granulated per hour to $\frac{3}{4}$-inch size and under varies from 2 tons to 8 tons.

Portable Crushing Plants, combining in one unit a stone breaker, screen, and elevator, are to be obtained, which, from the feeding operation, perform all the other stages automatically. The screen rejects stones of too large size and returns them to the crusher. This machine is especially useful for road work.

Elevators and Conveyors are of various types, fixed and portable and combined with screens. The buckets are mounted on dual chains in the high-speed intermittent type of elevator suitable for working sand and gravel. A more general type has the buckets fitted to a central chain.

In the belt conveyor the buckets are replaced by metal scoops, forming a continuous belt.

Screens of the rotary type are useful, particularly in road-making and concrete work, suitable for grading sand and gravel. These are fitted with a bevel gearing which drives a longitudinal shaft, in turn rotating the small rollers on which the screen rests. The screen is rotated by friction, and can be obtained 30 feet in length by 3 feet 6 inches in diameter, and is fitted with a special rejection cone which discharges the rejections at the feed end of the screen.

For Washing Sand and Gravel.—Washers, consisting of a cylinder rotated by the same method as the screen and having cast-iron or steel conveying blades attached inside, are obtainable. Screens may be used in conjunction with the washers for grading the aggregate for concrete.

WORKMANSHIP

The main requisite for good concrete, given good materials and the proper proportions, is no doubt satisfactory mixing. The basis underlying the making of concrete being that the cement should entirely fill the voids between the sand particles, and that the sand and cement should entirely fill the voids between the coarse aggregate, it follows that such an ideal condition can result only from the most thorough mixing in the first place, and from care in depositing and ramming or tamping during the operation of depositing. Other things being equal, the densest concrete will form the strongest and most impervious work.

For the best workmanship the concrete must be deposited as soon as mixed and small batches mixed at a time; and as has been said, there should be neither too much nor too little water used in the mixing. It will be found that too much water is more frequently used than too little. It is a mistake to think that this superfluous water can be got rid of without detriment to the resultant concrete, because even if it disappears by evaporation, it will bring the cement to the surface in so doing, which not only weakens the interior of the concrete, but causes dusting and crazing on the surface.

Curing.—Concrete will be stronger and less liable to craze and crack if it is allowed to dry slowly. In fact it is better to prevent any evaporation of water in the mix for at least seven days. Portland cement will set under water, and the presence of water during the setting period is essential to the chemical action which causes setting and hardening. Keeping the concrete in a moist condition is known as curing.

There are several methods of curing. Horizontal surfaces can be covered with damp sand or with waterproof building paper. Building paper is largely used, as it is cheap and convenient in use, and protects concrete floors, etc., from dirt and impurities while workmen are walking over the surface.

Sprinkling with water through a rose is a good method of curing, but it is necessary to protect the concrete from drying winds and hot sun and this can only be done by covering with building paper or damp sacking.

A properly cured concrete is less permeable than one that has been allowed to dry quickly. Curing concrete floors and pavings is also important because it tends to prevent dusting-up under traffic.

Dusting-up of concrete floors and pavings is a troublesome defect, especially in factories. Proprietary hardeners can be used as a surface treatment to prevent this trouble. A good treatment to harden the floor surface and prevent dusting-up is first to cure the concrete by covering with waterproof paper for about a fortnight (if ordinary Portland cement is used), and then to apply silicate of soda (waterglass). The grade known as P.84 should be used. This is a concentrated solution which should be diluted with four parts of water. It should be poured on from a watering can fitted with a rose and a clean mop should be used to spread it. Two or three applications are necessary, and these will harden the concrete to a depth of about $\frac{1}{4}$ inch. This treatment also waterproofs the concrete, and can be applied to damp cement renderings, concrete, and brick walls for this purpose.

Silicate of soda should not be mixed with the concrete ingredients or applied to a green surface, as this reduces the strength of the concrete. It can be successfully applied to old concrete which is dusting-up or admitting damp.

FROST

It is advisable that all work to concrete should cease during frosty weather. However, certain precautions can be taken to enable the work to continue. Braziers may be placed near the mixing and placing points, or aluminous cement used. The setting of this cement is accompanied by some rise of temperature. With ordinary cement the action of frost is to suspend the setting and hardening, and very severe frost will damage the crystals in the work already done. In the first instance, though the action is delayed, it will be resumed after the frost is over without any serious detriment to the strength of the concrete, but where damage is caused to the crystals the strength is permanently lessened.

When there is expectation of frost at night the surface of the green concrete work should be covered over with sacking or sawdust.

Where it is essential that the work should be continued during frost, and ordinary Portland cement is used, a wooden covering should be made to lay over and protect the new work.

Glycerine mixed with water lowers the freezing-point, and a 2 per cent. solution of calcium chloride and a 5 per cent. solution of salt are also recommended, but neither is desirable, salt in particular causing corrosion of the steel, and as has been frequently said, efflorescence is due to salt.

EXPANSION JOINTS

Though it might be thought that finished concrete formed an inert mass which would not be affected by differences of temperature, yet the fact is that it has a coefficient of expansion and contraction equal to that of steel. And though heat is generated by the cement in crystallising, the concrete actually contracts in setting. Consequently, unless the surface over which the concrete is laid is smooth, that is to say, if the forms are of very rough boarding or if the concrete is laid over some such rough material as brickwork, it will be prevented from creeping when contracting, with the result that cracks will appear on the surface and extend throughout its thickness. To prevent these cracks from this cause what are known as expansion joints should be formed in any large surface of concrete. These are formed by boards, metal strips, or bitumen joints. There seems to be no rule as to the distance apart of these expansion joints, but a safe principle is that they should be placed at the end of a period of concrete where, in the ordinary course, new concreting would be joined to that which has already begun to set.

BONDING NEW CONCRETE TO OLD

In this matter the Building Research Board have published their investigations in a bulletin entitled *Bonding New Concrete to Old*. The subject is one which merits investigation, in that faulty joints often occur at such junctions, which weaken the whole of the work. Cracks occurring in jointings permit not only percolation of water causing dampness, but the water having once entered may freeze, causing the concrete to be further disrupted. The water being rainwater also is very likely to have in solution chemicals which, having penetrated and crystallised, cause disintegration and efflorescence. The causes of the faults in jointing new to old concrete may arise from oil and grease having collected on the surface of the old work, and if the work is in situations where it is subjected to silt, the fault will be caused by the gathering of clay and scum, both of which prevent good adhesion. Where concrete forms part of deep foundations under construction all the silt and water must be pumped out and the surface of the concrete already deposited must be thoroughly cleaned off before the new concrete is laid in. The Research Board advise that where the concrete already in position is *not more than four hours old* the laitance film must be removed before the new concrete is laid in, as it prevents good adhesion. That is to say, the top layer of the concrete already deposited should be removed within four hours and the new added immediately and of not too dry a mix, as in that condition it is liable to be too porous. Where the concrete is *more than four hours old and not more than three days old*, the procedure advised is that the laitance should be removed, the surface brushed with a steel-wire brush, and then thoroughly washed with clean water but not hacked. A grout of cement mortar of not more than half an inch thick is then laid on, on top of which the new concrete is laid before the grout is set.

Where the work is *more than three days old* it is recommended that the hardened surface should be chipped away and brushed with a wire brush to remove all dust. It should then be cleaned with clean water and a slurry of neat cement applied with a brush. This should be worked well into all the interstices. The cement grout and new concrete are then laid in as before.

Columns.—In this matter of bonding new concrete to old and the previous one of expansion joints there enters the subject of the jointing between columns and floors which they support, when both are built of concrete. The formation of a column in concrete should be a continuous operation from base to top. The floor should never be laid on a newly constructed column until the column has had sufficient time to settle without being subjected to weight, and the joint should come at the junction of the column and the floor unless some special formation of reinforced beam work is provided. In this the beam carried by the column is tied to the column by the reinforcement, and there must be special arrangements made for expansion in the beams independent of the floor. The whole floor should be laid in in one operation.

WATERPROOFING

Though it would be reasonable to look upon concrete as an impervious material, yet it is only this when the construction is perfect in every respect. Faulty construction, mainly due to bad mixing, though also caused by imperfect tamping and the improper jointing of new to old work, causes voids and cracks which permit the water to percolate. To overcome this difficulty certain so-called waterproofing specialities are obtainable. Silicate of soda, as stated on page 162, hardens and waterproofs concrete, but it must be applied as a surface treatment after the concrete has set, and asphalt laid on externally will prevent the percolation of water, but in addition to these there are certain waterproofing powders and liquids to be obtained, such as "Cementone" products and "Pudlo."

Cementone Waterproofing Powder, which is known as No. 2 Cementone Product, should be mixed thoroughly with the dry cement. When thoroughly mixed the mixture should be passed through a fine sieve, after which the mixing with the aggregate is proceeded with in the usual way; but when using this powder the makers, Messrs. Joseph Freeman, Sons & Co., Ltd., strongly recommend that the mix be stiffly gauged and on no account sloppy. The proportion recommended is 5 pounds of the powder to each 100 pounds of cement, which it is claimed will make a gauging of 3 parts sand and 1 part cement thoroughly waterproof. The powder is packed in casks containing from 5 pounds to 100 pounds.

Another Cementone Product for Waterproofing is provided in a *liquid form*, to be applied to the exterior of the concrete surface, though it is not thought that this is likely to prove so satisfactory or so durable as the powder. One of the great objections to concrete is its cold, grey, unattractive appearance when made with Portland cement, and in this matter the Cementone products include permanent *colourings in powder form* which, being incorporated with the cement, give a permanency of colouring that is not only superficial but throughout the thickness of the concrete and therefore cannot be rubbed off with wear.

It is advised by the makers of these products that the secret of good Cementoned work is thorough mixing, which goes to confirm what has already been said with regard to satisfaction in concrete depending mainly on the thoroughness of the mixing operation.

No. 8 Cementone Product.—Though not actually regarded as coming directly under the heading of waterproofing, this product, which is a *Liquid Concrete Hardener*, is indirectly concerned with this subject, as it renders concrete less subject to frost, permanently hardening and strengthening it and making it non-porous. Tests carried out in the open, during an exceptionally hard winter, are stated to have proved that concrete made with this liquid hardener withstood 15° of frost, and the resultant concrete was harder than that gauged with ordinary cement under normal atmospheric conditions.

"Pudlo."—The manufacturers, Messrs. Kerner, Greenwood, Ltd., state that from data furnished by Dr. Johnson, of Cork University, the greater strength of concrete when their "Pudlo" Brand Waterproofer was included was due to the lubricating effect of the compound, which helped the particles of the aggregate to arrange themselves more easily, thereby producing a denser and therefore a stronger concrete. And as is stated in the *Handbook of Cement Waterproofing*, published by this Company, the reasons why a concrete may require to be waterproofed are the following:

"In order to produce the plasticity or workability, as it is sometimes called, so necessary for the flow of concrete into the required forms and for the easy rendering of cement mortar, it is essential to add more water than is necessary for the hydration of the cement. This surplus water forms minute cells or pores which, communicating with each other, become what are termed capillary canals that are capable of conveying water throughout the mass.

"It is obviously impossible to waterproof concrete or mortar effectively by the addition of any finely ground inert material or extra cement in the endeavour to eliminate voids, because such additions still leave it necessary to add an excess of water in gauging the mixture, and so do not affect the predominant cause of porosity. The addition of an excess of cement should be avoided not only on account of the expense, but because mixtures over-rich in cement are liable to develop surface cracks or crazing. These minute cracks are visible evidence of the expansion and contraction of the cement matrix. The expansion and contraction are caused both by changes of temperature and by changes in the moisture content of the cement mortar or concrete. To put it more plainly, any specimen of cement mortar or concrete will expand when it is heated or when it absorbs water, and will again contract when its temperature is lowered or when the contained moisture is removed.

"A very important fact which has a great bearing on the behaviour of Portland cement mixtures is that the expansion and contraction, consequent on the variation of moisture content, are on a far greater scale than the changes due to differences in temperature. It was established by exhaustive experiments conducted by the U.S.A. Government Bureau of Standards that when non-waterproof concrete is thoroughly saturated, it expands as much as if its temperature had been raised 1,000° Fahrenheit. It has also been shown, as a result of experiments made by Professor A. H. White in the Department of Chemical Engineering at the University of Michigan, that the expansion of specimens of neat Portland cement that had been continuously immersed in water was measurably progressive, although at a decreasing rate for 15 years. The total expansion during this period was equal to 0·162 of the initial length, and half of this expansion occurred in the first 2 months.

"The results of these investigations were summed up by Professor White in the following words: 'Alternate expansion and contraction due to changes in moisture are the greatest underlying causes of the destruction of concrete structures, for the strains due to volume changes produced by variations in the water content are usually far greater than those due to changes of temperature.' It will be seen that if by the waterproofing of the concrete or cement mortar the absorption is prevented, expansion is limited to the relatively small amount consequent upon changes in temperature, and this is almost negligible."

In this matter and to this end it is claimed for "Publo" brand waterproofer that the chemical substances of which it is composed are balanced so as to react with the constituents of Portland cement, and that an insoluble compound is thereby evolved which spreads and fills the voids. This action takes place immediately the initial set of the cement occurs, with the result that the outer surfaces setting first, they prevent the escape of water as they have become waterproof. In ordinary cement mixtures this escape of water by evaporation produces a minute honeycomb. The moisture thus imprisoned within the concrete remaining in contact with the granules of cement carries their hydration to a point where the contained water becomes chemically combined. This is accompanied by an increase in bulk, with the result that the space previously occupied by the uncombined water is filled by the hydrated cement expanded. This results in a concrete of a more dense nature, or in other words, the capillary pores are closed up.

The actual proof of this action is to be seen in microphotographs taken of sections of concrete in which this waterproofing has been used. The particles of sand and other aggregates are seen to be more densely placed, and the cement itself exhibits a density and freedom from cavities.

The proportions required of this waterproofing powder in cement concrete are as follows:

For Ordinary Conditions, i.e. dampness only: mix the concrete in the proportions 3 : 2 : 1, with 2 per cent. powder; render surface $\frac{1}{2}$ inch thick with 2 : 1 with 5 per cent. powder.

To resist Water Pressure: mix the concrete in the proportions 3 : 1 : 1, with 3 per cent. powder; render surface $\frac{3}{4}$ inch thick with 2 : 1 with 5 per cent. powder.

These figures, which are taken from the *Handbook* already quoted, depend naturally to a great extent on the condition of the workmanship. The proportion of the waterproofing powder is calculated in relation to the weight of the cement and not to the aggregate, thus 3 : 1 with 2 pounds of powder is 300 parts of sand to 100 parts cement, and 2 pounds of waterproofing powder to every 100 pounds cement.

In the matter of bonding new concrete to old referred to above, a cement grout was advised for jointing the new and old in work more than four hours old, and in that more than three days old. To form this grout so that it will be more efficacious, the incorporation of this waterproofing powder is recommended in the following manner:

Place the Portland cement in a heap, and add 5 pounds of the waterproofing powder to every 100 pounds of cement; well mix while dry, riddle through an $\frac{1}{8}$-inch wire mesh, which it is advised should be done out of the wind to prevent both the cement and powder blowing away;

then water with a hose or can with a rose until a stiff mortar results. Thin this mortar by the addition of water until it is sufficiently liquid to flow evenly over the surfaces. It is advised that a cement which has a slow initial set should be used, so that the slurry does not set before the concrete or rendering can be applied.

The methods advised for waterproofing concrete blocks with " Pudlo " brand waterproofer are the following :

Thin Facing during Manufacture.—When a $\frac{1}{4}$-inch cement facing is treated with " Pudlo " brand waterproofer it is sufficient to make the most porous block watertight. Such a thin surfacing must be applied while the block is being made, that is, before the concrete sets. Use 3 parts of coarse washed sand, 1 part of Portland cement, 3 pounds of powder to every 100 pounds of cement. This facing must be mixed wet, and not semi-dry, as the latter mixture is not satisfactory for thin facings.

For Rock-faced and Ornamental Dressings.—A waterproofed facing of not less than 1 inch in thickness is used. This facing may be composed of

7 parts of $\frac{1}{4}$-inch granite chips, flints, or pebbles.
3 parts of coarse washed sand. } This is $2\frac{1}{2}$: 1.
4 parts of Portland cement.
5 pounds of " Pudlo " brand powder to every 100 pounds of cement.

Mix this as wet as practicable, but do not make it so wet that it will stick to the mould or machine. When facings are mixed semi-dry, they are difficult to waterproof.

Porous Concrete Blocks, which were not waterproof when they were manufactured, may be rendered upon the outside or the inside of the building with cement mortar mixed with the waterproofing powder. Exterior renderings are preferable, because they keep the substance of the walls both airtight and dry, and so a warmer building is given.

Concrete Improvers.—In addition to the powders and liquids mentioned above, there are certain chemicals that, if incorporated with cement in making concrete, contribute to it certain properties which, though not definitely waterproofing, have that result by virtue of the addition of the properties that they do impart. For example, *silicate of soda*, when applied to the surface of the concrete after setting, forms a hard coating on the surface by converting the inert lime of which cement always contains a proportion into silicate of lime. Such an improver, as will be readily recognised, has considerable value in concrete made for surfaces over which there is to be a large amount of traffic, such as floors in factories and for roads. To expedite the hardening, *calcium chloride* is incorporated.

To make concrete more easily workable, and at the same time give it a greater density, impermeability, and uniformity, hydrated lime can be incorporated. Hydrated lime is quicklime slaked with water, and whilst the addition of quicklime to cement is detrimental, it is quite the reverse with a properly prepared hydrated lime. It serves to accelerate production. The extreme fineness of the hydrated lime enables it to fill the smallest void, and thus it acts as a moisture carrier to every particle of the cement, assuring the more complete hydration of the cement.

Hydrated lime has the power of absorbing moisture, which it readily gives up to the neighbouring grains of cement, and thus every particle of cement is properly hydrated. This too has an effect on the amount of water necessary to use in the making of concrete. The complete hydration of cement takes place in two stages: at first it is capable of taking up only a certain quantity of water, but later it takes up still more to complete the hydration. The actual quantity of water required for the chemical actions of setting and hardening varies, but the average is 9 per cent. by weight of the cement used; and as it is not possible to mix cement with this small quantity of water, more than is required must be supplied, the excess being about two or three times the actual. Within possible working limits, as has been explained, the smaller the quantity of the water used, the greater the strength, other things being equal. Consequently, in this matter the addition of hydrated lime is of great assistance, for it absorbs and retains moisture which the slow-acting cement can utilise.

The proportions of hydrated lime for concrete work are:

In 4 : 1 concrete: 10 per cent. of the weight of the cement.
In 6 : 1 concrete: 15 per cent. of the weight of the cement.
Partition slabs: 20 per cent. of the weight of the cement.

It is important that the amount of the hydrated lime used for concrete work should not contain more than 1 per cent. free lime, and the lime must be of the correct quality, free from any dust or rubbish which would prevent the thorough distribution of the cement.

As has been said, when the cement crystallises in concrete a gell is formed from which water is exuded, and there is a slight increase in the volume of the mix. The hydrated lime acts as a filler, and freely liberates its water to the cement, thus aiding in the final crystallisation; and to the extent that the plasticity is increased, and the resultant mass rendered more homogeneous, it may be said that the use of hydrated lime may be regarded as a waterproofing operation.

SWIMMING POOLS

The subject of waterproofing concrete for tanks having come much to the fore with the growth of open-air swimming tanks, the Building Research Station received a request for information on the subject from a Local Authority, and to this the following reply was given:

"The subject of the value of waterproofing admixtures for concrete is a highly controversial one, and an investigation has been started at this Station. The following observations, based on information at present available, may be of assistance. There is a very large number of integral waterproofing compounds on the market, and these materials are of various types ; many of them possess certain common characteristics, and they may be roughly classified by composition into the following categories.

Pore-filling.		Water-repellent.	
Inactive.	Active.	Inactive.	Active.
Chalk.	Alkaline Silicates.	Calcium Soaps. Waxes and Fats.	Soda or Potash Soap used alone or together with :
Magnesia. Talc. Fuller's Earth.	Sulphates of Aluminium or Zinc. Chlorides of Aluminium or Calcium.	Coal-tar residues and Bitumen. Vegetable Oils.	1. Calcium Chloride. 2. Alkaline Silicates. 3. Lime.
Gypsum. Iron Filings.	Iron Filings + Ammonium Chloride.	Resins.	
Silicates of Alkaline Earths.			

" 'Active' agents are those which depend for their effect upon the formation of insoluble products by means of chemical reaction, either with a secondary agent or with ingredients of concrete itself.

" The above represent ingredients which occur in known proprietary waterproofers. The actual product as sold may be in the form of powder, paste, or liquid, and may contain any of these ingredients either alone or in admixture. The ingredients are sometimes in solution or in aqueous emulsion with gelatine, glue, or casein, as the emulsifying agent. Some in powder form are incorporated with the dry mix and others are added to the gauging water.

" It is perhaps worthy of note that most of these preparations are of secret composition, and for this reason it would be inadvisable to attach great importance to any one series of experimental results, since the composition of a secret proprietary article may be completely altered at any time. Such changes in the composition of secret preparations are believed to have been made in certain instances which have been brought to our notice.

" In considering the advantages to be gained by the use of integral waterproofing compound, it is necessary to examine the manner in which penetration of water is likely to occur under practical conditions.

" In concrete work, the majority of the cases of serious penetration which occur are usually found to be due to the development of shrinkage cracks, or to defects in construction, rather than actual penetration of the mass of the concrete. Construction joints, cracks at angles, bonding of floors to walls, and voids in which formwork ties have been embedded, are the most common causes of penetration of moisture. It is extremely unlikely that the use of an integral waterproofing admixture would be of the slightest use in counteracting defects of this kind. Some time ago we investigated a case of serious percolation of water into the basement of an important building in London. A widely advertised integral waterproofing compound had been used, and, although the general mass of the concrete was dry, water had penetrated at numerous defective points of the kind just indicated, and had at times been sufficient to submerge the pumps provided for the ejection of sewage so that these were put out of service. In this particular instance the considerable extra cost involved by the addition of the integral waterproofer was certainly not justified by the results obtained."

LIGHTWEIGHT CONCRETE

The manufacture of lightweight concrete is in the nature of a specialist operation in which certain chemicals are combined with the concrete at the time of mixing, causing the water to be dissolved into its elements, and the hydrogen sets free and creates bubbles in the mixture. The bubbles expanding considerably become encased in cement, and the whole mass is expanded to such an extent that an extremely porous concrete results.

Another method of making lightweight concrete is that known as ice concrete, in which small balls of ice similar to hail are incorporated in the mix. These balls becoming coated with cement, as the ice thaws the water is set free, leaving circular cavities of air surrounded by cement only.

SURFACE FINISHING AND COLOURING

The surface of concrete walling, which in its natural state presents a somewhat drab and uninteresting appearance, may be treated in a variety of ways to relieve this deadness and at the same time to remove the marks left by the forms. Also the formation of walls of roughcast and stucco, which are generally regarded as plastering, are in reality forms of concrete, the constituents being sand, gravel, and cement, just as in concrete.

Paint Finishes.—Special paints for covering cement and concrete surfaces are now widely used. Ordinary oil paints often give trouble owing to the saponification which results, especially on new cement surfaces.

The special paints are of two kinds : one incorporating Portland cement and the other a water- or oil-bound paint. They may be applied with brush or spray, and light colours are preferable to dark. Two coats are usually applied. This is sufficient to conceal the grey colour of the cement and to hide any blemishes. The cement paints are the more durable : they add to the water-resisting quality of the wall and they may be washed down. There are several proprietary brands of paint for covering concrete. One brand has a porous and elastic nature which enables the wall to " breathe " and does not craze.

Gunite Renderings.—The application of cement mortar as a rendering $\frac{1}{4}$ inch to 2 inches thick is particularly useful in repairing old walls. It is applied with a cement gun, which results in great density and strong adherence. On new work the gunite is usually applied as a thin coat, crushed stone and coloured cement being used. This gives a natural stone texture and pleasant colour. Ordinary materials are liable to be patchy in tone when they dry out.

Rendering over Concrete Walling would seem to be a rather unnecessary operation, and a better method of applying a finish to a concrete wall than to render a cement wall with cement in order to give it a decorative appearance is to form the outer face of the concrete wall with moulds of a rusticated surfacing in reverse. This can be done at very little additional cost, and at a cost far less than that of rendering the wall in plain cement mortar, which should be entirely unnecessary if the workmanship is what it ought to be in the first place, and which necessitates scoring the concrete and the application of cement with wooden floats. Further, when finished such rendering is rarely satisfactory, as there is no proper bond with the wall behind, and in the effort to get a good surface the workman is inclined to trowel too industriously, which generally results in crazing.

So far as the appearance of the finished wall is concerned, the above remarks apply equally to *hammering* and *rubbing*. Hammering consists of removing the outer film of cement with a square-headed bush *hammer* which has a chequered surface, or pneumatic tools are now in use for this work, the object of such operation being to give a texture to the surface which, by reason of its many faces, will break up the light and produce variety. The same effect to a lesser extent is to be obtained by brushing the concrete with wire brushes and by *rubbing down* with carborundum.

A far better way of relieving the dullness of a concrete wall is to introduce colour into the concrete at the time of erection. This may be done by either of two methods ; firstly, by mixing in with the cement mineral pigments, and it is important to note that these should not be applied as a surface treatment only but incorporated so that they extend throughout the mass. And if proper pigments are chosen, this can be done without in any way weakening the set. The second method of colouring concrete is by using coloured aggregates. Proprietary dry mixes are obtainable in a range of colours and textures. These are used for the surface concrete only, owing to the high cost.

STUCCO

As one of the most frequent causes of unsatisfactoriness in stucco work is the peeling off of the stucco, and the main cause of this is water getting in behind the stucco, it is essential that all forms of protection against damp should be taken. Unless the stucco becomes badly cracked damp cannot enter through the stucco, but the weak points will be angles and openings which should be very carefully flashed ; in fact, if the ordinary precautions advised for any other form of construction be taken there will be no danger of the water getting in behind. These are : that horizontal surfaces, copings, and cornices should be sloped to shed the water, and all water tables, belt courses, and sills and any other projections should be sloped on their upper surfaces and throated on their under projections.

Where frame construction is used, provided that the foregoing precautions are taken, there will be little danger of water penetrating to the interior of a building, owing mainly to the protective effect of the air in the interior of the frame wall. But it should be noted that it is not advisable, where the stucco is worked on to metal lathing, that it should be continued down to the ground level, but it should be terminated a foot or so above the ground line on a water table, the framework being supported at that height on a concrete masonry or brickwork foundation.

Mixing and Applying.—The proportions recommended for mortar should be 1 bag of Atlas Portland cement to 3 cubic feet of sand, and 5 pounds of dry hydrated lime, and for the finished coat, the Atlas White Portland cement should be in the same proportions. It is in this finishing coat that the colouring pigment may be used in the proportion of 10 pounds to 1 bag of cement. *Application :* when applying to masonry the surface of the wall must be thoroughly wetted, and the first two coats after being applied must be thoroughly scratched. Each coat should also be wetted before the next is applied. The thickness of the base coats are from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch, and the total thickness of the three coats should be not less than $\frac{7}{8}$ inch from the masonry surface. The time which elapses between the application of the base coat and the second coat must not be more than 24 hours and that between the finished coat and the second coat at least 7 days, and the under coat must be kept wet for at least four days after application.

Lathing.—Stucco on metal lathing should consist of a mixture of the same proportions, and the last should be of expanded metal of a weight of not less than 3·4 pounds per square yard painted or galvanised after expansion, or a woven wire cloth not lighter than 19-gauge wire, $2\frac{1}{2}$ meshes to the inch, with stiffeners on 8-inch centres, galvanised or painted after weaving. Unless the lath is self-furring it should be applied over furring strips of either galvanised or painted metal, not less than $\frac{3}{8}$ inch thick. Underneath the lathing and above the sheeting which is fixed on the outside of the framing there should be waterproofing paper. The metal lathing should be fixed with $1\frac{1}{4}$-inch 14-gauge galvanised or painted staples not more than 12 inches apart. These last should be placed horizontally. The vertical joints should be made to come over the furring strips, and be secured with the same staples not more than 4 inches apart. Horizontal joints must be lapped or butted and laced with 18-gauge galvanised wire at the corners of the building. The furring strips should be fixed at least 6 inches back from the corner, and the lath bent round the corner. The application is the same as that already described for masonry, with the difference of course that the metal lathing does not require to be wetted.

Stucco should never be applied during frosty weather, and so far as its application to masonry or concrete walling is concerned, a very wise measure to take against the peeling off already referred to is to build on the outside of the concrete wall a hollow clay-tile outer skin, on to which the stucco may be applied.

Back Plastering.—As the sheeting referred to above is apt, by reason of its shrinkage, to cause cracking in the stucco, a method known as back plastering is used to enable the sheeting to be omitted.

Framing.—For this the studs of the framing should be placed at distances not exceeding 16 inches, and they should be tied together just below the floor joists with 1 × 6-inch girts, which act as sills for the floor joists in addition, and the angle studs forming the corners of each wall should be braced diagonally with 1 × 6-inch boards let into the studs on their inner sides. There should be in the height of each storey a horizontal bridging of 2 × 4 inches 1 inch back from the face of the studs. The omission of the sheeting renders the diagonal bracing of all angles essential. This should be of 1 × 6-inch boards, 6 or 8 feet long, let into the studs on their inner side in such a manner as not to interfere with the back plastering.

Furring.—Direct on to the studding there should be fastened $\frac{3}{8}$-inch galvanised or painted crimped furring, and on to this the metal lathing, of not lighter than 19-inch gauge and $2\frac{1}{2}$ meshes to the inch with stiffeners of 8-inch centres, should be fixed horizontally. The staples should be of $1\frac{1}{4}$-inch 14 gauge, not more than 8 inches apart over the furring or stiffeners. The corners should be lapped as before described.

Insulation.—An air space in back plastering may be provided by fixing building paper or Cabot's Quilt to the studs by means of wood strips nailed over the folded edges of the material at a distance of about 1 inch from the back of the stucco. *Application :* when the base coat is sufficiently hard a coat of stucco should be applied on the inside between the studs, at a time not less than a week later. The second and the finish coats are applied inside and out, making a total thickness of stucco of about $1\frac{1}{4}$ inches.

WEIGHT (APPROXIMATE)

Mixture : 1 : 2 : 4 per cubic yard.

Materials.	*tons.*	*cwts.*	*lb.*	*Materials.*	*tons.*	*cwts.*	*lb.*
Brick (broken)	1	6	0	Gravel (pit)	1	7	0
Coke Breeze	1	0	46	Kentish Rag	1	18	0
Clinker	1	0	73	Limestone	1	12	60
Flint	1	15	0	Portland Stone	1	15	0
Granite	1	19	0	Reinforced (average)	1	16	18
Gravel (Thames ballast)	1	14	100				

QUANTITIES

Amount of cement in pounds, sand and aggregate in cubic feet required per square yard :

Proportions.	Materials.	4 inches thick.	8 inches thick.	12 inches thick.
1 : 2 : 4	Cement	59·3	118·6	177·9
	Sand	1·32	2·64	3·96
	Aggregate	2·62	5·24	7·86
1 : 2½ : 5	Cement	48·9	97·8	146·7
	Sand	1·35	2·70	4·05
	Aggregate	2·7	5·4	8·1
1 : 3 : 6	Cement	41·5	83·0	124·5
	Sand	1·43	2·86	4·29
	Aggregate	2·86	5·72	8·58

CHAPTER 9

CONCRETE CONSTRUCTION AND REINFORCED CONCRETE

THERE are three methods of concrete construction :

1. Mass or plain concrete.
2. Reinforced concrete (normal and pre-stressed.
3. Pre-cast concrete (plain or reinforced).

Plain concrete is in some respects comparable to brickwork or masonry, except that there are no joints other than the " construction " joints between one day's work and the next. Plain concrete is a strong material in direct compression but is comparatively weak in tension and sheer. Large areas are liable to craze and crack through shrinkage, and this is a fault which can only be avoided by introducing light reinforcement.

Reinforced concrete is a combination of cement concrete and steel. The steel is so placed that it takes tensile and sheer stresses while the concrete takes the compressive stress. Thus, the properties of both materials are used to the best advantage. Suitable reinforcement also takes the stresses due to shrinkage of the concrete, so that cracking and crazing are reduced to negligible proportions.

Pre-cast concrete is concrete cast into a mould, allowed to set and harden, and then removed and fixed into position as a constructional unit. Pre-cast concrete products are now manufactured in elaborately equipped factories, mechanical methods producing a well-consolidated, strong, dense material. In some products steel reinforcement is incorporated.

MASS OR PLAIN CONCRETE

Mass (unreinforced) concrete is used for foundations, over-site covering under wood joist and board floors, filling up under heavily loaded solid floors, filling up under steps, solid floors laid on the ground or on hardcore filling, walls of small buildings, boundary walls, steps, retaining walls, backing to facing bricks and masonry, etc.

Proportions.—The proportions of cement and aggregate vary according to the nature of the materials and the nature of the work. Two average mixtures may be considered as suitable for most mass concrete jobs, as follows :

1 : 6 mix. Composed of 1 part cement to 6 parts coarse aggregate. The coarse aggregate to pass a 2-inch ring and to be well graded with a

reasonable proportion of fine material. If fine material is lacking, a proportion of sand should be added. The aggregate to be clean river or pit ballast.

1 : 2 : 4 mix. Composed of 1 part cement, 2 parts sand, and 4 parts aggregate to pass a $\frac{3}{4}$-inch mesh and to be well graded down to $\frac{1}{4}$ inch. The sand to be clean pit or other sand to pass $\frac{1}{4}$-inch mesh and be retained on a $\frac{1}{16}$-inch mesh.

Foundations.—For most foundations the 1 : 6 mixture is quite strong enough. For small buildings, the concrete should be 12 inches thick and should project 6 inches on either side of the wall footings. Thus, a wall 9 inches thick requires a foundation 2 feet 6 inches wide by 12 inches thick. This is suitable for such buildings as houses on rather weak but stable ground. The depth below ground level should be at least 2 feet, and in the case of clay 3 feet, so that no movement can occur through atmospheric conditions causing the ground to shrink or settle.

On strong ground, such as compact sandy gravel, a concrete foundation 2 feet wide by 9 inches deep is sufficient for houses and other light loads.

The concrete foundation should project under piers.

Column foundations should be of adequate area and depth to spread the load over the ground. It is advisable to haunch up steel columns in concrete brought up to ground level. This prevents corrosion.

All trench bottoms should be levelled before placing the concrete. On sloping sites the foundations should be stepped. A look-out should be kept for weak spots, filled-up holes, and changes in the nature of the subsoil. Any weak spots should be excavated and filled with concrete

On fine sand or other subsoil which is liable to squeeze out and move laterally when heavily loaded, special precautions should be taken by constructing retaining walls, sheet piling, or piling under the foundations.

Surface Concrete.—The surface or over-site concrete should be of 1 : 6 mix laid over the whole area of the building at levels to suit the floors.

Under wood joist and board floors the surface concrete is usually laid so that a clear space of at least 12 inches is left between the concrete and the floor joists. This enables the under-floor to be adequately ventilated by means of air bricks and honeycombed sleeper walls. On firm ground which has been levelled after removing the surface soil the concrete can be laid direct on the ground, but any filling to levels should be done with broken brick or dry clean ballast hardcore well consolidated by ramming or rolling, and the surface concrete should be laid on this. On firm, well-drained ground the surface concrete under joist floors may be 4 inches thick, but on weak or damp ground it should be 6 inches thick.

On clay or other ground which holds water near the surface it is advisable to waterproof the top 1 inch of concrete or to lay it in two thicknesses with a damp-proof membrane (asphalt, bituminous felt, etc.) in the middle. This should be turned up the walls and sealed against the horizontal wall dampcourse.

Surface concrete for hard pavings and floorings, as in kitchens, garages, yards, etc., should be 6 inches thick of 1 : 6 mix laid on a bed of well-consolidated hardcore. For heavily loaded pavings and floors, as in industrial buildings and public garages, it is advisable to reinforce the concrete (1 : 2 : 4 mix). In some cases 9-inch-thick slabs with double reinforcement are necessary.

Concrete Hearths.—The space within the fender walls of a ground-floor fireplace should be filled with hardcore, well rammed, and a 4-inch thickness of concrete of 1 : 6 mix.

Concrete hearth slabs to upper floors of wood should be laid on temporary boarding or sheeting. The slab should be supported on the chimney breast at one side and on a wood fillet nailed to the trimmer joist on the other. Alternatively, a brick trimmer arch can be built to span from the chimney breast to the trimmer joist, the surface of the hearth being levelled up with concrete.

Retaining Walls.—Plain concrete retaining walls of 1 : 2 : 4 mix are suitable for heights up to 5 feet, but above that it is usually cheaper to use reinforced concrete. For a retaining wall to retain a 3-foot bank of moderately firm earth or filling, a wall 14 inches thick at the base battered to 9 inches thick at the top, and with a suitable foundation, is sufficient. Weep holes should be formed to drain water from the retained ground and the wall should be backed with stones or hardcore to allow the water to reach the weep holes.

Walls.—As already stated, unreinforced walls are liable to develop cracks through shrinkage. But mass concrete walls up to 10 feet high and 20 feet long will not crack if the concrete is properly cured (see page 162). Thus, if the evaporation of moisture is retarded by covering with building paper or other means the shrinkage will be greatly reduced and will produce nothing worse than fine crazing. To further retard drying, the building paper should be removed after two days (with normal Portland cement concrete) and the wall sprayed with water through a rose. The paper should then be replaced.

The concrete for footings and walls should not be thrown from a height but laid in carefully between the shuttering. This is best done with a shovel, though on large jobs chutes are used. The concrete should be placed in layers about 2 feet deep and carried right round the walls to this level, but it should not be allowed to set before placing the next layer, except at the end of the day's work. The precautions to be taken in resuming work the following day are described later.

The concrete should be gently tamped. Consolidation by vibration is necessary to make a dense smooth-faced concrete and for this purpose electric or pneumatic vibrators may be attached to the shuttering.

Suitable reinforcement must be placed over wall openings to take the place of lintels.

Steps.—Poured concrete steps may be formed with a 1 : 6 mix where strength is not important, but a surface rendering of fine concrete will be required. Granolithic mix is best for this purpose.

Steps laid direct on earth must have wood forms placed in position to form the risers. Shuttering will be required to form balustrade walls. Concrete steps should be not less than 6 inches thick. The finished surface should have a slight forward fall for drainage.

Brick-faced Walls.—Walls with brick facing and concrete backing require shuttering at the back only. The brickwork should be allowed to set for a few hours before placing the concrete, and the concrete should be placed in 2-foot horizontal " lifts." The brickwork should be 2 feet in advance of the concrete.

A course of headers should be placed to every four courses of stretchers to bond the brick facing to the concrete, or metal ties can be used.

Expansion Joints.—Large concrete areas or long lengths should be divided into bays by expansion joints. This will also minimise shrinkage cracks. Expansion is caused by the natural hardening process as well as by temperature increase.

Expert opinion varies as to the distance apart of expansion joints. A reasonable distance appears to be 50 feet. In concrete roads and paved areas the expansion joint may consist of a special asphalt strip (see Chapter 4, Vol. 1). In floors and walls a special cranked metal strip may be used to bridge the expansion gap, which can then be filled with a mastic material. In boundary walls where weather penetration is of no importance an open rebated joint may be used. The expansion gap is usually formed by inserting a suitable strip of oiled wood which is withdrawn when the concrete has set.

Pipe Holes and Chases.—It is cheaper and neater to form pipe holes and chases in concrete walls and floors while the concrete is being poured. Oiled cardboard tubes can be used for this purpose. Short lengths of asbestos-cement tubes are suitable where a smooth hole is required, these tubes being left in position.

REINFORCED CONCRETE

Principles.—As already stated, steel reinforcement is introduced into concrete to take the tensile and sheer stresses, leaving the concrete to take the compressive stress.

A reinforced concrete beam is illustrated in Fig. 160. In this example there are three reinforcing bars placed near the bottom of the beam in the position where maximum tension occurs. The bars are cranked at the ends. The centre bar is turned upwards at 45 degrees near the ends to take the maximum sheer stress which occurs near beam ends.

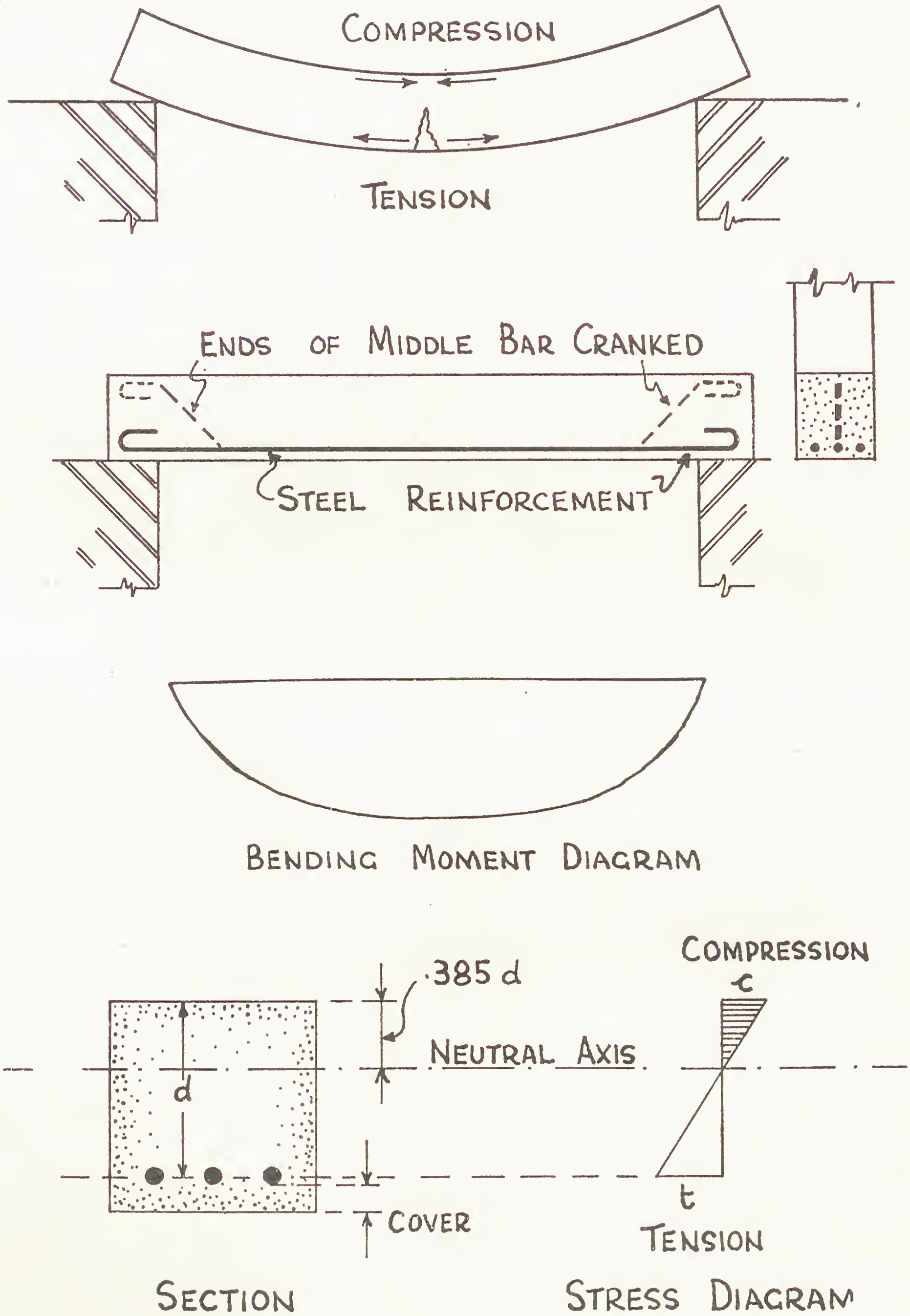


Fig. 160.—Reinforced concrete beam.

The above is a simple type of reinforcement suitable for lintels of moderate span and loading. Larger lintels and beams are usually reinforced against sheer stress by steel stirrups placed at intervals which are most closely spaced near the ends, the spacing being widest in the middle.

The steel reinforcement of a reinforced concrete column is designed

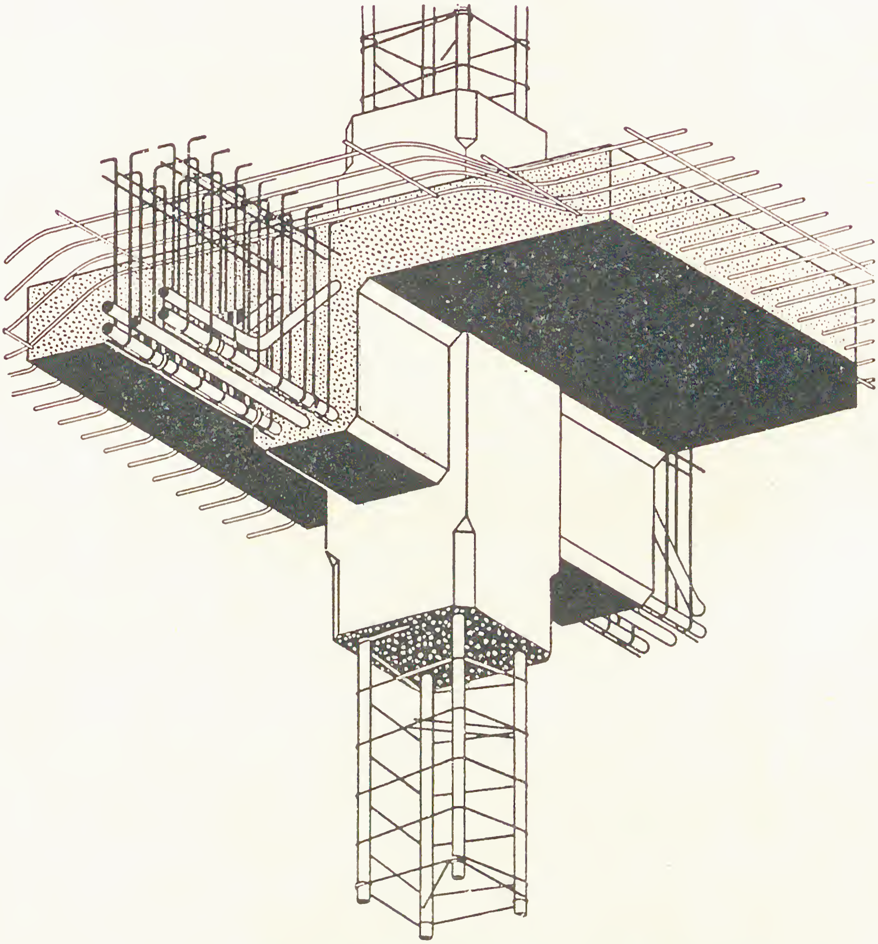


Fig. 161.—B.R.C. reinforcements at junction of column, beams, and floor.

to resist the stresses due to bending. Thus, as the column bends the steel on the outside of the curve takes the tensile stress. The usual reinforcement consists of a steel rod placed near each corner of the column, the four rods having wire wound round at even spacing. Fig. 161 illustrates the junction of a reinforced concrete column with the ends of two beams and a suspended concrete floor. Such a system of construction is continuous and homogeneous in contrast to the older system of columns and beams with free end fixing and wood joist floors. A result of this continuity is that there is a wider distribution of stress, so that a load on one beam produces stress in all the beams and columns throughout the structure.

Floor and Roof Slabs.—Although the reinforcement may consist of separate mild-steel rods spaced 4 inches to 6 inches apart, it is now usual to adopt a steel fabric or mesh reinforcement. This may be of steel cut and expanded from sheets (expanded metal) or steel wires with cross wires at right angles to the main reinforcement and electrically welded at the intersections (welded steel fabric). These reinforcements are supplied in sheets or rolls and can be cut with suitable tools. They can be bent to any reasonable shape and used in any position. They have

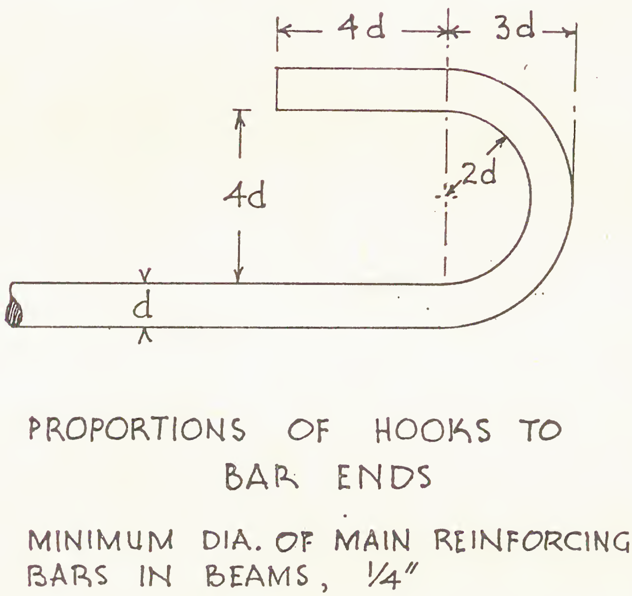


Fig. 162.—Reinforcing bars should be hooked at the ends, as shown.

the advantages of ease of laying, economy of labour on the site, and accuracy in placing. The makers issue design tables from which the correct weight of reinforcement can be readily selected according to the live load to be carried and the span.

The same conditions of free and fixed ends already described for beams apply to slabs, and with fixed ends (continuous over supports) there is some economy of reinforcement owing to the bending moment being less than with free ends.

It is important to place the reinforcement to follow reversal of stresses due to continuity. The diagrams in Fig. 163 show how reinforcement should be bent to achieve this.

To avoid excessive deflection the thickness of the slab should be not less than one-thirtieth of the span.

Hollow and Pre-cast Floor Units.—Ordinary reinforced concrete floor slabs require close-boarded shuttering which must remain in position until the concrete has attained sufficient strength to be self-supporting. Such slabs are, of course, solid, and the strength of the material near the neutral axis (through the middle of the slab thickness) is not fully

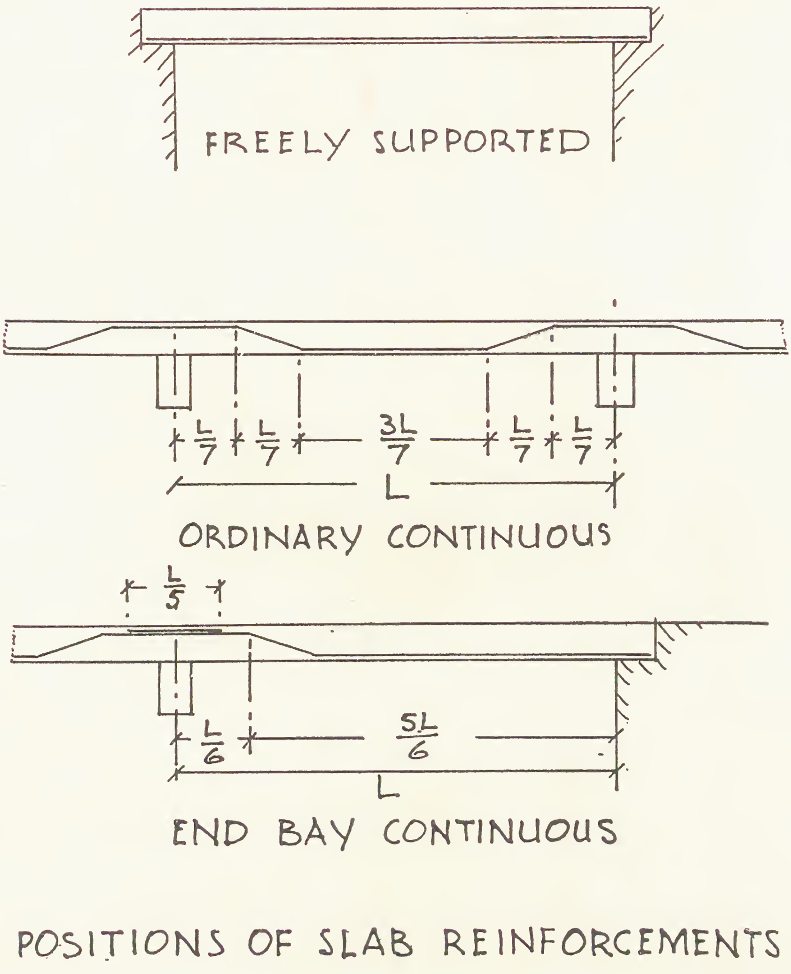


Fig. 163.—Reinforcement must be placed to follow the plane of tension which varies according to conditions of slab support.

utilised, so that solid slab construction is rather wasteful and heavy, and the slab cannot be loaded immediately.

There are many proprietary systems of hollow clay blocks and pre-cast reinforced concrete units which overcome these disadvantages of the solid slab. There are also systems of shuttering specially designed for use with hollow blocks and which avoid the forest of props which is necessary with the solid slab. Other systems of steel trough shuttering are made which are used for producing a poured concrete floor of channel shape, the ribs being reinforced and forming closely spaced beams.

The hollow clay units are small enough to be easily lifted and placed in position by one man. The spaces between the blocks are filled with poured concrete in which reinforcement has been previously placed. The tops of the blocks are covered with an inch or two of concrete. These blocks are obtainable with scoured or keyed soffits which can be plastered. The blocks are placed on the shuttering and are then concreted. A system of telescopic steel centres may be employed in some cases. These can be adjusted to span from wall to wall or beam to beam and no props are needed.

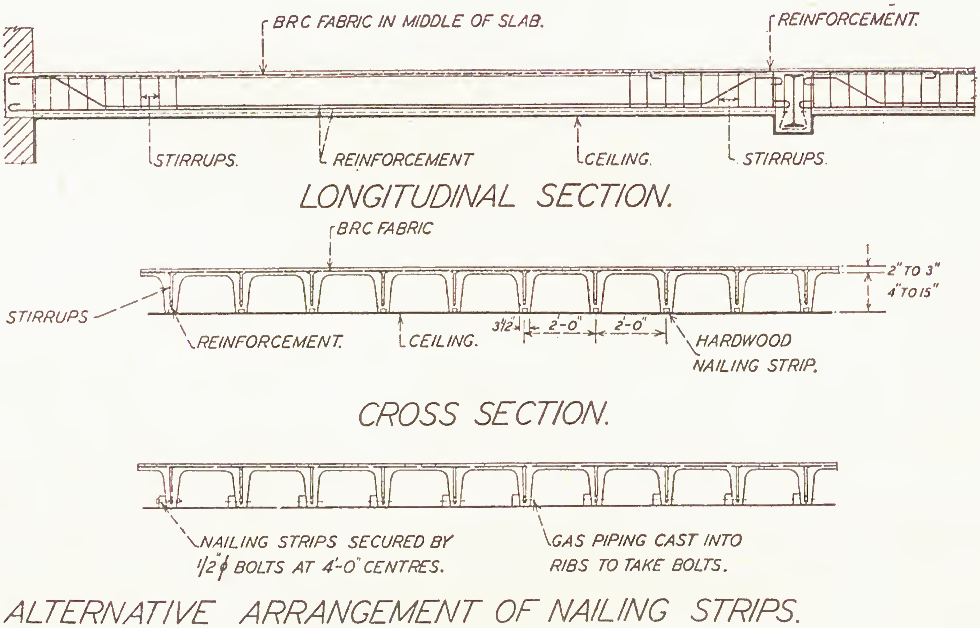


Fig. 164.—Steel tiles used as temporary forms in reinforced concrete floor of inverted trough section.

Pre-cast reinforced concrete beam units are made in various patterns: hollow, channel, or I-shaped. These units rest at the ends on the walls or main beams. The spaces between are reinforced and filled with concrete in some cases, or merely grouted in others. The tops are surfaced with an inch or two of concrete. The soffits can be plastered. No shuttering or supports are required with these units and they will bear the weight of workmen, barrows, etc., as soon as fixed. If rapid-hardening cement is used for grouting and surfacing, the floors can be loaded within a few hours of fixing.

Bending.—Whereas it used to be customary to bend the steel on the site, certain firms now specialise in bending the steel in accordance with the schedules. This saves the use of considerable time as the specialist firms are provided with suitable tables and bending apparatus, and as

Fig. 165.—SEIGWART PRE-CAST CONCRETE FLOOR BEAMS.

much of the steelwork in reinforced concrete work is now standardised it will be possible to purchase a good deal of it from stock.

Where it is decided to bend on the site it is important to see that all bending is carried out cold. The pressure must be gradual and even, as any jerkiness of action will tend to crack the steel. The operation requires a table of about 20 feet long and a bar bender at each end so as to avoid turning the bar.

In placing the steel the reinforcement should, as far as possible, be wired up before it is inserted into the beam box. The actual number and position of the bars must be obtained from the steel schedule, and the quantity required in each position placed against the position where it is required before the work is commenced to ensure that none of the bars are missing. The reinforcement drawings will show which bars pass over and which under others, and these should be followed exactly, the bars being placed in position in the order necessary to bring about this result. As a general thing the steel in the main beam should be placed first, next that of the secondary beams, and lastly that to the slab. All main bars should be carefully and securely wired to the stirrups, as this is an additional precaution against the movement of the reinforcement steel during the tamping of the concrete already referred to. In addition to what has already been said with regard to the necessity for accurate placing of the reinforcing steel, it should be noted that steel placed in a wrong position is as bad as if it were omitted, and may be worse.

The Special Spacing Blocks already referred to are of great value in securing the correct placing of the steel, as they will not only space the bars at the correct distance from the face of the beam, but also from the soffit. The tendency of cranked slab bars to fall sideways may be prevented by wiring a spare bar across the top of the cranked ends.

Cutting Reinforced Concrete.—Any holes required should be cast in the concrete during its construction and not cut subsequently. Special tapered circular plugs are to be obtained for casting small holes for pipes, and for larger holes a frame box must be used. It will be realised that any such hole must not be permitted to interfere with the position of any of the reinforcement. And if such a hole exceeds 1½ inches in diameter the plug should be surrounded by a spiral wire coil.

Special Structures.—The following hints are given by the Trussed Concrete Steel Co. with reference to special structures: "In the construction of a retaining wall the method to be adopted in carrying out the reinforced concrete work must be fully considered before the shoring to the excavation is put in hand, to ensure that re-shoring is eliminated and that the wall can be executed in any lengths between two shores and that the shores do not interfere with any main members of the design such as columns, beams, or counter forts.

"Where a retaining wall is to withstand water pressure it is important to make an efficient joint between each section. This can best be done by forming a splayed joggle joint and thoroughly roughing the concrete face. If this is in such a position that it cannot be got at for hacking the use of a retarder painted on the stopping board will be found very efficient. Before casting the next section all dust or loose particles should be removed from the old concrete, which should be thoroughly soaked and grouted with cement. Particular care should be taken with the ramming of the new concrete at this section.

"For all waterproofed structures particular care must be taken in the selection and grading of the aggregate.

"When concreting a water-tank or other structure designed to withstand or to contain a liquid the amount of concreting per day should be so designed that a complete ring of the structure can be cast in order to avoid vertical joints. The horizontal joint must be thoroughly cleaned before the next day's work. There is a tendency for the scum of the cement to collect at the top, which may be set quite hard by the next morning but will never be watertight. The removal of this scum is best done by scraping the cement after the initial set and washing the scum out with a strong jet of water. An inch of stiff grout poured into the centering immediately before concreting is commenced will assist in obtaining a strong and watertight joint.

"Through-wire ties or bolts should always be avoided in such structures as it is almost impossible to block the holes left after their removal. If wires are left in the concrete the rusting of these will continuously stain and disfigure the work. There are many types of special clamps on the market which are quite effective and which obviate the necessity for these holes or wires.

"For all large structures it is necessary to consider" (and this is more important in reinforced concrete work than in ordinary concrete work, in which connection the following has already been explained) "the question of expansion and contraction joints. Such joints should be provided with a view to taking up any of the movements resulting from the expansion or contraction in steel, and the concrete due to a variation in temperature above or below the average pertaining during the hardening period of the concrete, also any movements due to the natural contraction in the concrete during the ageing or hardening period. This latter will depend on the nature of the concrete, and the conditions of curing, and has little relation to the strength of the concrete. When such joints have been incorporated in accordance with the instructions of the architect or the engineer, care must be taken that corresponding joints are made in any finishing material applied directly to the structure. Contraction cracks in concrete floors will usually coincide with the stopping joints between the various days' work. The corresponding joints should therefore be left in the granolithic, terrazzo, or other mastic floor covering. It is seldom worth while to allow a contraction joint in plastering as this is more easily repaired."

Finally, it should be remembered that material should not be loaded on to a newly built reinforced concrete floor during building operations, as the concrete cannot be expected to take even the working load for which it has been designed until two months at least have elapsed. A suitable place for such stacking of materials can always be found over walls or columns. There is a distinct responsibility placed upon the foreman for any accident which may occur from such overloading or from failure to follow the drawings supplied, and a wise foreman will take no instructions from anyone other than the architect or the engineer in charge of the work to make any alterations from the drawings, and these only if in writing.

Pre-stressed Concrete.—In pre-stressed reinforced concrete the parts where tensile stress is induced by normal loading are pre-stressed by compression to such an extent that, when normally loaded, tension in the concrete is almost completely avoided.

Methods.—Pre-stressing is being increasingly used in the production of pre-cast reinforced concrete products designed to take structural loads.

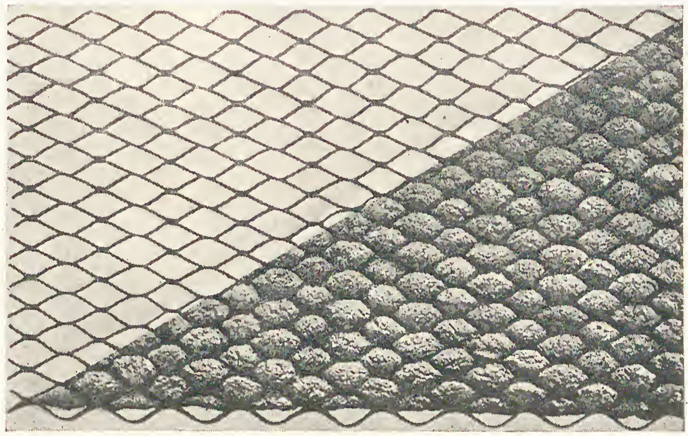


Fig. 166.—Expanded metal reinforcement. (*By courtesy of the Expanded Metal Co., Ltd.*)

Methods of pre-stressing may be divided into two structural groups: First, pre-tensioning, in which steel tensile wires are bonded to the concrete, the wires being stretched before the concrete hardens. Second, post tensioning in which the steel wires are not bonded to the concrete and are stretched after the concrete has hardened. The ends are secured by anchorages which prevent the wires moving when the pre-stress load is removed.

Pre-stressed concrete members can be made only under scientific control with special plant. Greater skill and supervision is needed than in ordinary reinforced concrete.

The advantages of pre-stressed concrete include: saving in weight; smaller cross sections; saving in steel; increased strength in shear; freedom from stress cracking and crazing of concrete.

"*Exmet*" reinforcement is used for reinforcing concrete block work and also for reinforcing brickwork, partition slabs, etc. This is manufactured from mild steel and is stocked in 20, 22, and 24 gauges, in $2\frac{1}{2}$-inch, 7-inch, and 12-inch widths, in standard coils 70 or 75 feet long. It is also supplied in flat strips of similar gauges and widths up to and including 16 feet long. It is also used in almost any form of pre-cast concrete slab such as, for example, those used to cover electric cables laid in the ground, and it is also used for concrete kerbing constructed on the work.

Any form of the foregoing meshes is suitable for use in forming open-work partitions, shop divisions, fencing, guards for machinery, windows, trees, lockers for clothes, tools, etc., and many similar and fireproof articles.

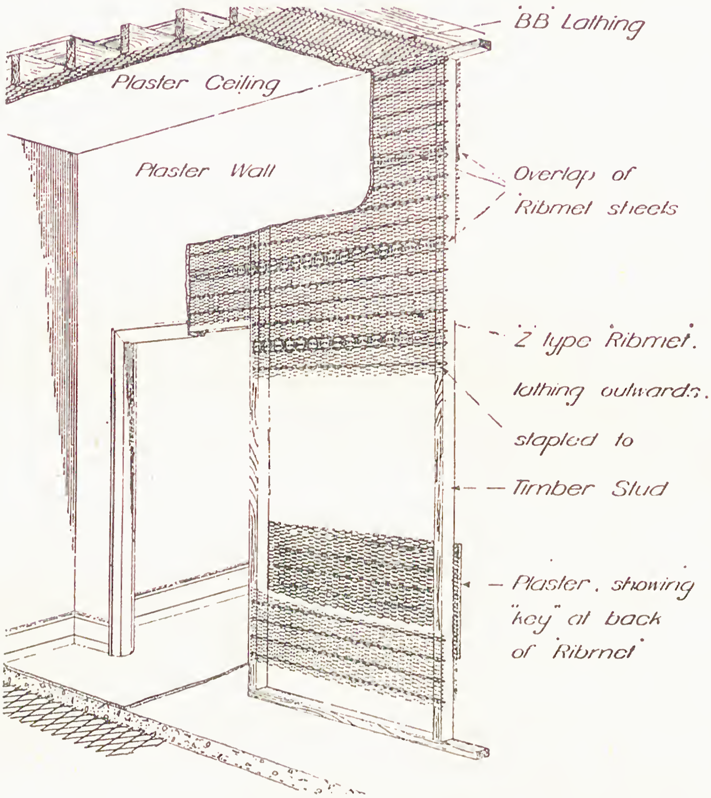


Fig. 167.—"Ribmet" in partition.

"*Ribmet*" is a product of this same company, which consists of their expanded metal lathing in combination with V-shaped ribs. The lathing is either grooved to receive the ribs or the ribs are attached to the flat sheet of lathing with the meshwork passing straight across the opening of the ribs. The ribs may be spaced apart at practically any required distance. The standard sheets are 2 feet wide, the short way or mesh by 2 feet to 9 feet long, and sheets up to 12 feet long can be supplied, though there is an extra charge for odd lengths. A property of "Ribmet," rendering it suitable for reinforced concrete work, is that it can be bent into any special shape desired. Sheets having their ends bent down to the required length and angle are suitable for placing between rolled steel joists to rest on the bottom flanges where the concrete flooring or roofing is to be haunched down to the flanges. This is particularly helpful where the underside is to be plastered, when the bottom flange of the joist may be encased in metal lathing of the type known as the "BB" and plastered over. For plaster work to a false beam or an air duct or a pilaster the sheet will require to have its ends bent upwards.

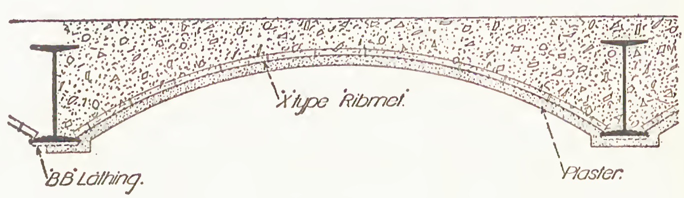


Fig. 168.

"Ribmet" may also be curved or cambered to any radius required. The bending is done by an ordinary plate-bending machine of the three-roller type. This can be worked by hand so that the bending may be done on the job.

Ceilings, Arches, and Beams.—That type of "Ribmet" known as the "Z" type, being the one in which the lathing passes over the openings of the ribs, is particularly suitable in suspended ceilings, false arches, walls, and partitions, as it gives a continuous and unbroken lath face and key for the plaster. This should be fixed the long way of the sheet from bearer to bearer, and the strands in the various sheets should always slope in one direction. In vertical work they should slope inwards and downwards from the plaster face. This reinforcement should be fixed at each rib to the bearers supporting it, and it should be wired together at 3-inch to 4-inch intervals between the supports. The sheets should be overlapped not less than one mesh where they join and the overlap should not come at angles.

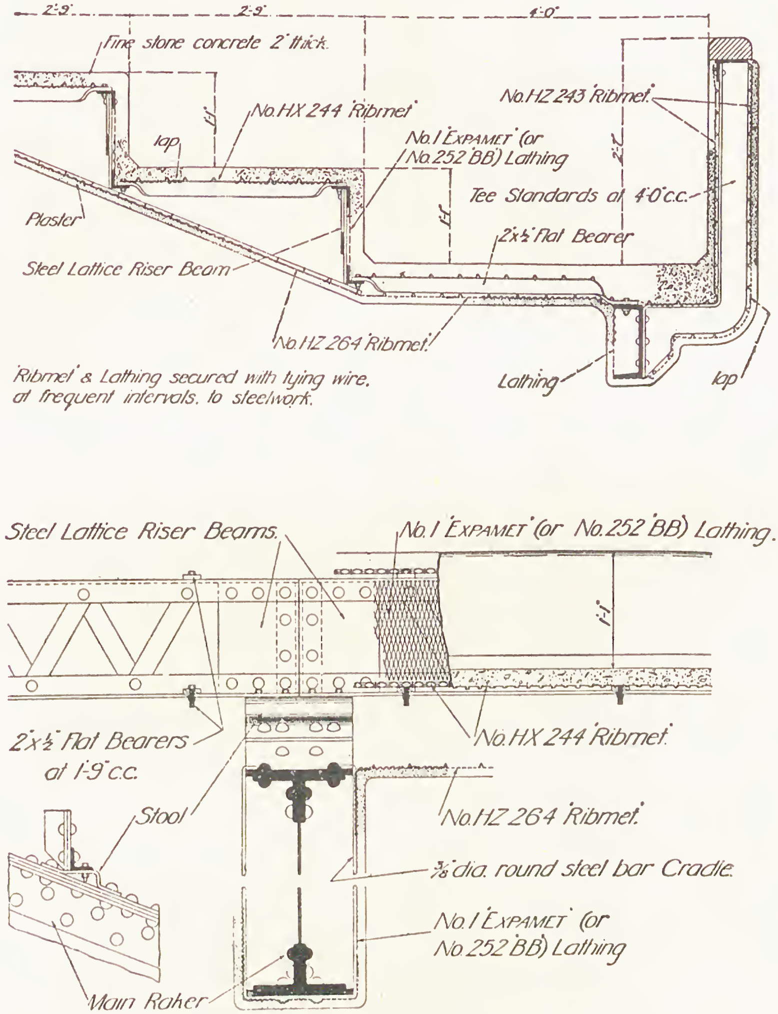


Fig. 169.—Encasing steelwork. (*By courtesy of the Expanded Metal Co., Ltd.*)

Encasing Steelwork.—Where reinforced concrete, floors, roofs, and stairs are constructed in steel frame buildings, the stanchions, girders, and joists should also be protected from fire to render the building fire-resisting. For this, the steelwork should be encased in "Ribmet," on which the plastering is done. The sheets of expanded metal are wrapped round the steelwork with the lathing outwards and are tied together with wire at the overlapped joint and covered with plaster, or, in better-class work, to render the protection still more fire-resisting, the spaces between the lathing and the stanchions may be filled in with concrete.

Floors and Roofing.—The reinforcement for concrete floors and roofing is rendered permanent and fire-resisting by the use of "Ribmet" in conjunction with any type of flat or arched slabbing. The reinforcement is laid directly on to the joists and the concrete placed upon it. The underside is covered with expanded metal lathing of the type known as "BB," and the whole of the underside is finished with plaster. The "Ribmet" should be placed with the ribs uppermost, and with the ribs running from support to support, and the sheet should be overlapped two meshes at all joints and wired together at 3-inch to 4-inch intervals along the sides, and at each rib at the ends.

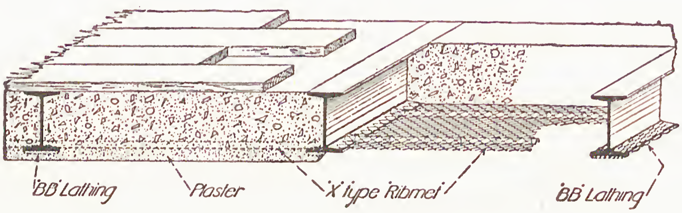


Fig. 170.—"Ribmet" flooring.

For suspended concrete flooring, the "X" type is preferred; that is, the type in which the lathing is grooved to receive the ribs, because the lath corrugation stiffens the rib.

It is essential in the course of the work that no load should be placed on the "Ribmet" before the concrete is laid and the slabbing set, and runways should be formed for materials and workmen to take the weight off the metalwork.

Continuous Flooring.—Floors to support heavy loads over long spans are constructed of the "X" type of "Ribmet" used in conjunction with 3-inch mesh "Expamet" reinforcement. The main reinforcement is bedded in the concrete, the "Ribmet" being laid on the ribs, and the "Expamet" on the underside forms the underface to receive the plaster finish.

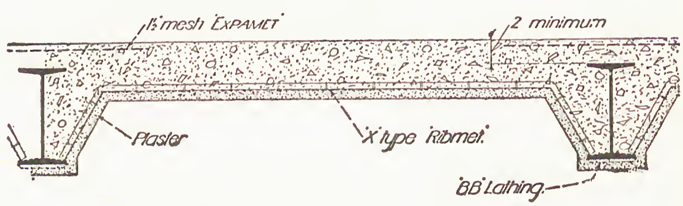


Fig. 171.—Continuous flooring.

The tables show the safe superimposed load for flooring and roofing of supported slabs and continuous slabs in which "Expamet" expanded steel slabs are used. It is not generally economical to use thicknesses below the zig-zag line in the tables.

The sheets should be laid the long way of the mesh in order to obtain the full tensile strength of the expanded metal, and where overlapping occurs this should not be of less than one mesh. Where suspended slabs are supported only at their ends a layer of reinforcement throughout near the underside of the concrete is sufficient.

For slabbing continuous over several spans there must be a separate tension strip near the top of the concrete placed over the intermediate supports and extending to the points of contraflexure.

For the reinforcement in the bottom of the slab the sheets may be butted on the supports. When laying the reinforcement the sheets should be so placed that all the strands slope in one direction. For the bays at the end chases must be left in the wall to provide a bearing of not less than 3 inches for the end of the slab. Corbels or offset courses will of course supply the same purpose.

Tension strips form a reinforcement for the tensile stresses caused by the upward bending over intermediate supports in continuous slabs. These should be of sufficient length to reach the points of contraflexion. For a continuous slab the usual length of tension strip is about two-fifths of the span to cover average loading conditions.

Concrete Recommended.—The following proportions for concrete used with "Ribmet" are recommended:

For floors and roofs up to $3\frac{1}{2}$ inches thick, 3 parts of coarse aggregate to $1\frac{1}{2}$ parts of sand, to 1 part of Portland cement. For thicknesses over $3\frac{1}{2}$ inches use 4 parts of coarse aggregate, to 2 parts of sand, to 1 part of Portland cement. The average weight of the reinforced concrete may be taken as 12 pounds per inch of thickness per foot super. Cinders and coke breeze are not recommended for this type of reinforced work.

For steelwork in casing, flooring, and similar work, hard broken brick, or hard furnace clinker, may be used. All these must be free from combustible material, old mortar, ashes, and dust, and other deleterious matter. The size of the coarse aggregates will vary from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch. The sand should be clean, sharp, gritty, and hard, no grain being larger than $\frac{1}{8}$ inch. The cement should be Portland cement or a quick-setting brand.

Tests.—A test on a floor formed of flat slabs supported on the bottom flanges of rolled steel joists, the slab being 3 feet long by 2 feet wide by 3 inches thick and being reinforced on the underside with "Ribmet." After a period of seasoning of forty-five days, steel forgings, scale weights, and iron pigs were placed on the slabs. One slab failed when the load reached 10,017 pounds, another at 8,017 pounds, and a third at 8,960 pounds, which gives an average of 1,800 pounds per square foot uniformly distributed and superimposed.

A Second Test made with arched slabs 8 feet long by 2 feet wide, 4 inches thick at the crown, and 12 inches thick at the haunches, supported on the bottom flanges of rolled steel joists, both reinforced on the underside with "Ribmet," gave the following result: After seasoning for 50 days the load was applied, causing one specimen to fail at 12,668 pounds, and the other 11,201 pounds, or an average of 1,131 pounds per square foot uniformly distributed and superimposed.

A Third Test on arched slabs 24 feet 3 inches long, by 2 feet wide, and 3 inches thick at the crown and over the top flanges of intermediate joists, and 9 inches thick at the haunches, each supported on rolled steel joists, spaced 6 feet centre to centre, reinforced on the underside with "Ribmet," gave the following result: After a seasoning period of 50 days

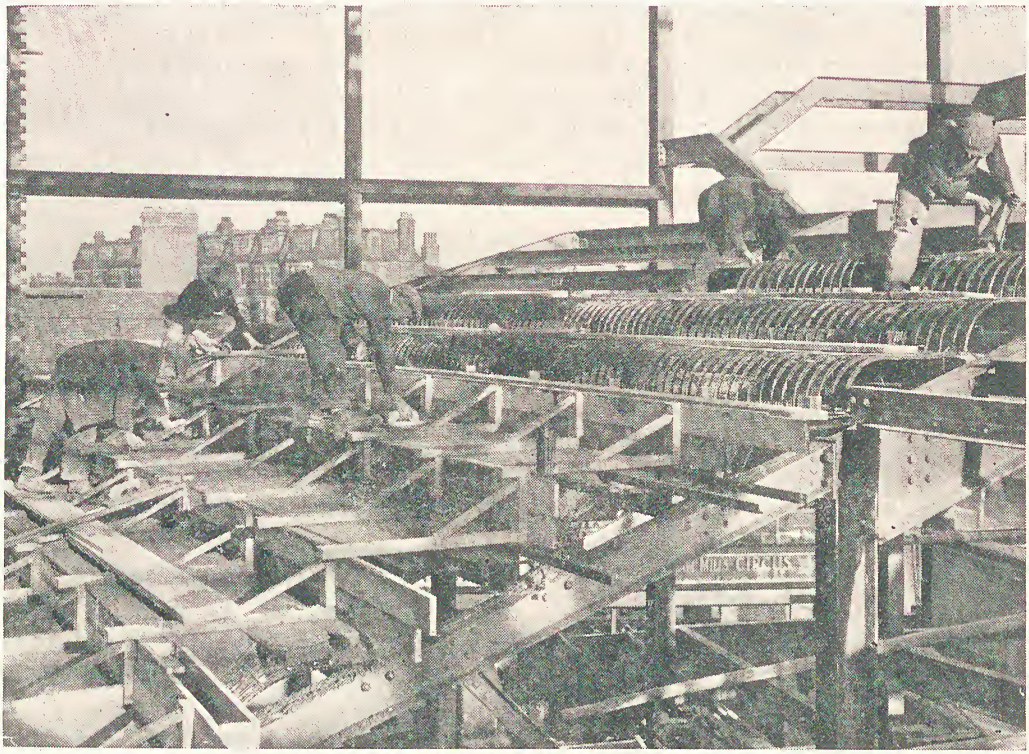


Fig. 172.—Cinema balcony of "Hy-Rib" ribbed expanded metal and concrete.
(By courtesy of the Trussed Concrete Steel Co. Ltd.)

the ultimate load on the two centre bays of one slab was the equivalent of a uniformly distributed and superimposed load of 619 pounds per square foot, and on the other 516 pounds per square foot, or an average of 568 pounds per square foot uniformly distributed and superimposed load.

A Further Test carried out on arched slabs composed of concrete of 4 parts of gravel aggregate, 2 parts of sand, and 1 part of "Steelcrete" gave the following results: One slab was composed of plain concrete and the other of similar concrete reinforced with "Ribmet." After 15 days being allowed for setting, a load 3 cwts. per square foot uniformly distributed was imposed. After 28 days, the slabs were loaded to destruction. The results were as follows for the first slab: After 15 days, a load of 18 cwts., 2 qrs., 13 pounds gave a deflection of $\frac{1}{8}$ inch and a load of 1 ton, 5 cwts., 2 qrs., 9 pounds gave a deflection of $\frac{3}{16}$ inch, whilst 2 tons, 0 cwts., 3 qrs., 7 pounds gave a deflection of $\frac{5}{16}$ inch, and a crack appeared $\frac{3}{4}$ inch from the centre of the slab and extended 2 inches from the soffit. After 28 days, the following loads gave these results: 3 tons, 9 cwts., 1 qr., 5 pounds, equals $\frac{5}{16}$-inch deflection; 5 tons, 12 cwts., 1 qr., 26 pounds, equals 1-inch deflection, in both of which the crack

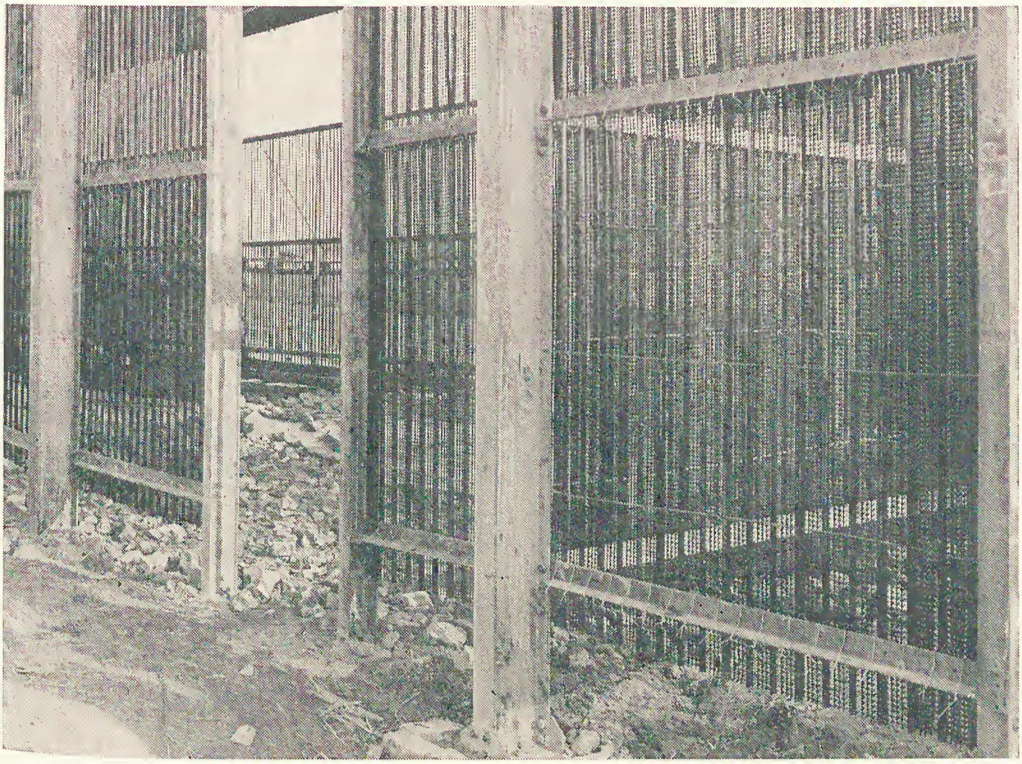


Fig. 173.—"Hy-Rib" ribbed expanded metal partition ready for plastering.
(By courtesy of the Trussed Concrete Steel Co. Ltd.)

opened gradually; at 5 tons, 13 cwts., 3 qrs., the slab collapsed. This is equivalent to a uniformly distributed load of 7 tons, 11 cwts., 2 qrs., 18 pounds, or 980 pounds per square foot, including the dead weight of the slab.

For the second slab, the following results were given: After 15 days, with a load of 1 ton, 5 cwts., 1 qr., there was a deflection of $\frac{1}{16}$ inch, with a load of 1 ton, 16 cwts., 3 qrs., 18 pounds, the deflection was $\frac{1}{8}$ inch, and with a load of 2 tons, 0 cwts., 1 qr., 17 pounds, a deflection of $\frac{3}{16}$ inch appeared, but there was no sign of a crack. After 28 days, with a load of 2 tons, 12 cwts., 3 qrs., 11 pounds, there was a deflection of $\frac{5}{16}$ inch, and with a load of 3 tons, 8 cwts., 2 qrs., 20 pounds, there was $\frac{1}{2}$-inch deflection; with 4 tons, 3 cwts., 3 qrs., 5 pounds, the deflection was $\frac{5}{8}$ inch.

With 4 tons, 18 cwts., 3 qrs., 22 pounds, there was a $\frac{3}{4}$-inch deflection. With 5 tons, 18 cwts., 3 qrs., 27 pounds, the deflection was 1 inch. With 6 tons, 4 cwts., 1 qr., 15 pounds, the deflection was $1\frac{1}{8}$ inch, and with 6 tons, 17 cwts., 3 qrs., 24 pounds, the slab collapsed.

Reinforced Concrete Roadways.—The practice of reinforcing concrete for roadways is rapidly increasing. This is generally now accepted as the best type of construction for roadways carrying large volumes of traffic and the excessive weight and speed of modern mechanically propelled vehicles. In this form of construction, the previously described "Expamet" expanded steel of a 6-inch mesh is used. It is made in sheets of any length, the long way of the mesh, up to and including 16 inches by any width short way of the mesh up to and including 64 feet. Where the traffic is likely to be heavy the concrete foundations should be not less than 6 inches thick, reinforced with 6-inch mesh "Expamet" of a weight of from $9\frac{1}{2}$ pounds to $5\frac{1}{2}$ pounds per yard super, according to the subsoil, and for lighter traffic concrete $4\frac{1}{2}$ inches to 5 inches thick, reinforced with a weight from $5\frac{1}{2}$ pounds to 2 pounds per yard super. The steel may be laid 2 inches from the top surface when the concrete rests on a good base and not less than 1 inch from the underside where the ground is unreliable. To allow for expansion in the concrete the roads should be constructed in bays having transverse expansion joints of tarred felt, bitumen sheeting, asphalt, or tar, dividing them at every 25 feet to 50 feet run of roadway. The reinforcement must be discontinued at these joints.

In the construction of concrete roadways, reinforced in this way, tamping is a very important matter, particularly against the board used for forming the expansion joint, and all concrete roadways should be watered while setting to prevent them drying out too quickly.

In the latest forms of reinforcing concrete for roadways, the upper and lower reinforcements are wired together to form a rigidly connected treble layer reinforcement.

The resistance to tension of concrete is practically nil, whilst it is very strong in compression; consequently, it is desirable to reinforce concrete against diagonal tension.

As a rolling load passes over a road, the weight is transmitted from the vehicle to the road through the wheels, and whilst the four wheels are close together, to produce four separate loads, the load has four points of contact with the road. This has the result that the lower parts of the slab directly below the applied load are in tension; and as the vehicle moves the stresses in the affected area of the slab change from tension to compression in the bottom fibres, and from compression to tension in the top fibres, and consequently a diagonal tension is set up. An actual demonstration of this was to be seen some years ago in Whitehall between the Cenotaph and Westminster Bridge end. An experiment was made with rubber paving, one of the results being to cause the blocks of rubber to creep in the direction of the course of the traffic with the result that after a time the lines of the joints between the blocks formed two arcs of circles in the nature of an S in the opposite halves of the road. Consequently, to overcome these different stresses, reinforcement is required at the bottom in a flat layer, and at the top in another flat layer with a corrugated intermediate layer, composed of diagonal strands. To meet these stresses the treble layer "Expamet" reinforcement was designed, and has been found eminently successful.

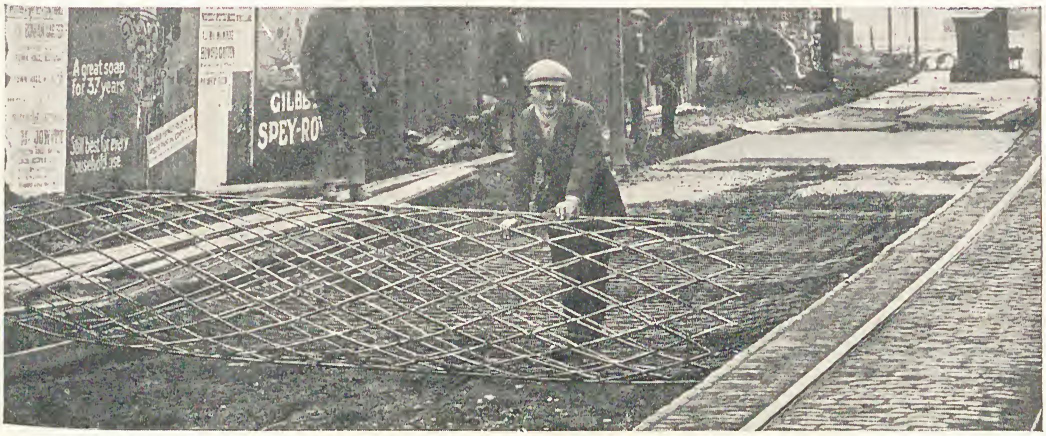


Fig. 174.—Laying the reinforcement in roadmaking.

Rapid-hardening Cement.—For roadways, more perhaps than for anything else, rapid-hardening cement is particularly suited. Especially is this the case where repairs are being carried out to roadways necessitating one-way traffic, and for use with expanded metal the above-described reinforcement is as suitable as for ordinary concrete.

PRE-STRESSED CONCRETE

If tensile stress is applied to the steel reinforcement during construction, it applies compression to the concrete where tension is normally applied by the load. It thus tends to neutralize the tensile stress in the concrete, which in normal reinforced concrete tends to cause cracks.

High-strength concrete and high-tensile steel wires are used in making pre-stressed concrete members. There are several methods and devices for pre-stressing, but they are of two distinct types, as follows:

Pre-tensioning.—The steel wires are stressed in tension before the concrete is placed. The stress is transferred to the concrete chiefly by bond between the concrete and the steel, though anchor blocks may also be used.

Post-tensioning.—The concrete is placed before the steel wires are tensioned. Tension is applied when the concrete has attained sufficient strength, and is transferred to the concrete through anchor blocks.

Pre-stressed concrete members are of smaller section and lighter than normal reinforced concrete. Floor units, beams, columns and other pre-cast products are now available, of pre-stressed manufacture. The saving in weight and the resulting easier handling, transport and erection, as well as the convenience of the smaller sections in saving space and reducing light obstruction in buildings, generally offset the extra cost. The sizes of the sections are about the same as structural steel sections suitable for similar spans and loading.

The production of pre-stressed concrete needs special plant and skilled supervision.

"***Self-Sentering*" *Expanded Metal.***—A ribbed form of expanded metal is manufactured by the Self-Sentering Expanded Metal Co., Ltd., and known as "*Self-Sentering.*" This is made from cold-drawn British steel sheets, and has ribs at $3\frac{5}{8}$-inch centres, nine ribs to a sheet, of a standard width of 29 inches, the metal between being drawn out into a diamond-shape mesh. It is supplied in lengths of 1 inch to 12 inches, increasing by 1 inch.

In addition to the adhesive area offered to the concrete the diamond mesh forms a perfect mechanical bond, for which it is claimed that, on an average, this bonding surface is eleven times that of an equivalent sectional area of round rods. A particular point made on behalf of "Self-Sentering" is that it is designed so that whilst it allows the excess water to drain off, it does not permit the fine stuff in the concrete to pass. "Self-Sentering," with the last-described reinforcement, is to be obtained in arched or curved patterns, which are suitable for arched floors, and suspended ceilings, the curved "Self-Sentering" being placed between the rolled steel joists and supported on the bottom flanges thereof, and the concrete laid in over.

The instructions given for fixing "Self-Sentering" are as follows: A layout or fixing plan is prepared by the manufacturers, on receipt of an order, and bundles of "Self-Sentering" are marked to correspond with the fixing plan. Where temporary supports are required they should be fixed before the "Self-Sentering" is laid. The extreme side ribs of adjacent sheets are lapped and firmly punched together at intervals of 18 inches along the length of the lapped ribs, commencing not more than 6 inches from where the ends of the sheets rest on the flange of the joists. In small arches not allowing this spacing the punching should not be more than 4 inches from the abutments and at the crown of the arch. These punches are supplied with the material, but on completion of the work, if the tool is returned in good condition, its cost is credited. (See Fig. 180.)

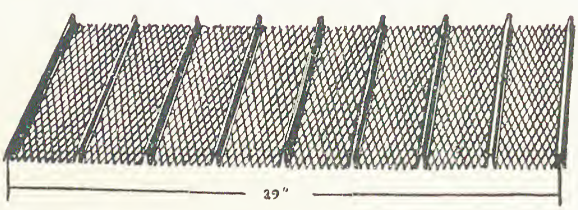


Fig. 175.—"Self-Sentering."

When the temporary supports have been finally adjusted to the correct level, and all shavings and foreign matter have been removed, the concreting may be proceeded with; commencing from the crown, concrete about 3 inches thick should be laid over the "Self-Sentering," after which the concrete is brought to the required thickness at all parts. The proportions of the concrete are as follows: 1 part of best British Portland cement to 2 parts of clean sand, free from organic, earthy, or other impurities, graded so that it will pass through a ¼-inch mesh, and at least 80 per cent. through a ⅛-inch mesh, to 4 parts of well-washed pit or river ballast, which should be retained on a ¼-inch mesh and pass a ¾-inch mesh. Coke breeze or boiler ashes are not recommended. The concrete should be turned three times dry and three times wet, and mixed to a quaky consistency so that it can be laid without tamping, though it may be lightly punned.

Where temperature rods are specified, they are embedded in the concrete over the joists, when the level of the underside of such rods is reached.

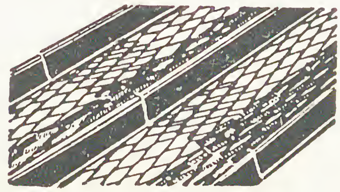


Fig. 176.—Detail enlarged.

It is inadvisable during concreting to make a break in the span, so that if it is impossible to complete concreting in the day the break in the work should be in a line parallel with the ribs and should be formed up to a vertical face. Before commencing laying concrete after such a stop, the vertical face of the old work should be well roughened and grouted by brushing on a mixture of cement and water of a creamy consistency and the new concrete immediately laid.

Flat Slab Floors.—A particular advantage of "Self-Sentering" used in the construction of flat slab floors is that the centering acts not only as reinforcement, but also does away with the necessity for any shuttering.

For fixing the flat slab floors the "Self-Sentering" is received in bundles marked as before explained, and if any temporary support is

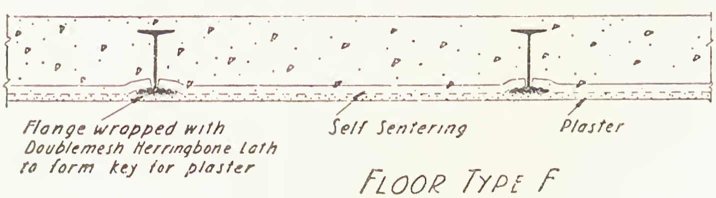


Fig. 177.—Continuous floor. (*By courtesy of the Self-Sentering Expanded Metal Co., Ltd.*)

required this should be put in before the "Self-Sentering" is placed. The sheets are laid in with the ribs uppermost, with their ends bearing over the joists on the shelf angles or on the beam casing. The side ribs of each sheet are lapped and firmly punched together at intervals of not more than 2 feet. The end laps of the sheet, if over supports, must be at least 3 inches long, and if between supports not less than 9 inches long. The laps over supports must be clinched by punching at every rib with two clinches. Between supports each rib is punched at not more than 2-inch centres. Before punching, see that the ribs are firmly interlocked. To sheets resting over the edges of beam boxes give a 2-inch bearing at either end. To facilitate the placing of the concrete the mesh may be cut 2 inches up the side of the ribs and pressed down the side of the beam boxing. Wedge up all temporary supports, remove shavings, and all other foreign matter from the mesh, before concreting is begun. This should be laid in first over the permanent supports and spread from each support to the middle of the span. When it is necessary to form a join

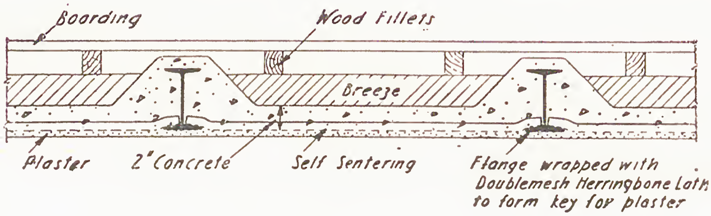


Fig. 178.—Flat floor slabs. (*By courtesy of the Self-Sentering Expanded Metal Co., Ltd.*)

in a span the break should be made parallel to the ribs, against a plank to give a vertical face. As before, when new work is applied to that partially set, the existing edge must be roughened and grouted. Alongside every rib, rods are laid, at $3\frac{5}{8}$-inch centres, at $7\frac{1}{4}$-inch centres along the side of every second rib, and at $10\frac{7}{8}$-inch along the side of every third rib.

Where the slab is continuous over supports the rods usually have the alternate ends turned up, and if continuity rods are required, they are embedded in the concrete over the joist when the level of the underside of such rods is reached. These should have at least $\frac{1}{2}$ inch cover of concrete, and as with all other forms of reinforced concrete, the reinforcement must be spaced exactly in accordance with the drawings.

The spans for temporary supports for "Self-Sentering" supporting various thicknesses of wet concrete are given in the following table :

Gauge.	Thickness of Slab.					
	1 inch.	2 inches.	3 inches	4 inches.	5 inches.	6 inches.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
24	4 9	3 9	3 0	2 8	2 4	2 2
26	4 6	3 2	2 8	2 4	2 0	1 8
28	4 0	2 10	2 4	2 0	1 8	1 4

The weight of concrete slab in pounds per foot super is given in the following table, the concrete being 150 pounds cu. foot :

Thickness, in inches . . .	2½	3	3½	4	4½	5	5½
Weight, in pounds . . .	31	38	41	50	56	63	69
Thickness, in inches . . .	[illegible]	6½	7	7½	8	8½	9
Weight, in pounds . . .	75	81	88	94	100	106	113

(*For floor loads, see page 292, Volume II.*)

For filler joist construction a floor constructed with " Self-Sentering " laid in between the bottom flanges of the joists and filled in above with concrete, the underside of the " Self-Sentering " being plastered and the bottom flange of the joist being wrapped with double herringbone lath, will be found satisfactory.

An adaptation of the above floor to be used where weight and depth of floor must be kept to a minimum is the following : " Self-Sentering " is laid in between the bottom flanges of the joists as before, and the bottom flanges wrapped with double herringbone lath (see Fig. 178). In between the joists the concrete is kept down to 2-inch thickness only, the joist itself being completely covered in concrete. A filling is then put in of breeze concrete to fill up the sinkings between the joists, and on this filling wood fillets are placed to carry the boarding of the floor.

The makers advise that when forwarding orders or enquiries concerning floors of the foregoing type, the following information should be given : (1) Provide, if possible, plans and section, showing the layout of steelworks, walls, etc., with any variations in the levels of joists marked thereon, and clearly indicate the total area to be covered ; (2) sizes of joists and all centre-to-centre dimensions ; (3) the type of floor required, and if continuous, what cover is being allowed over joists ; (4) the super-imposed load per square foot which is to be worked to, or alternatively, the purpose for which the building is to be used ; (5) method that is to be adopted for casing the joists ; (6) thickness of concrete desired.

A form of corrugated expanded metal, also supplied by the same company, is that known as " *Trussit.*" This is mainly used for the construction of solid reinforced partitions. It is particularly suitable for spans between supports, and produces a finished partition from 2 inches to 3 inches thick. The corrugations should be placed in the run of the shortest span, which may be either horizontal or vertical. During plastering this reinforcement needs temporary support at right angles to the span at 5-inch centres, until the scratch coat on the opposite side of the supports has set.

Other forms of ribbed expanded metal manufactured by the Trussed Concrete Steel Co., Ltd., are known as " *Hy-rib* " and " *Jhilmil.*' The

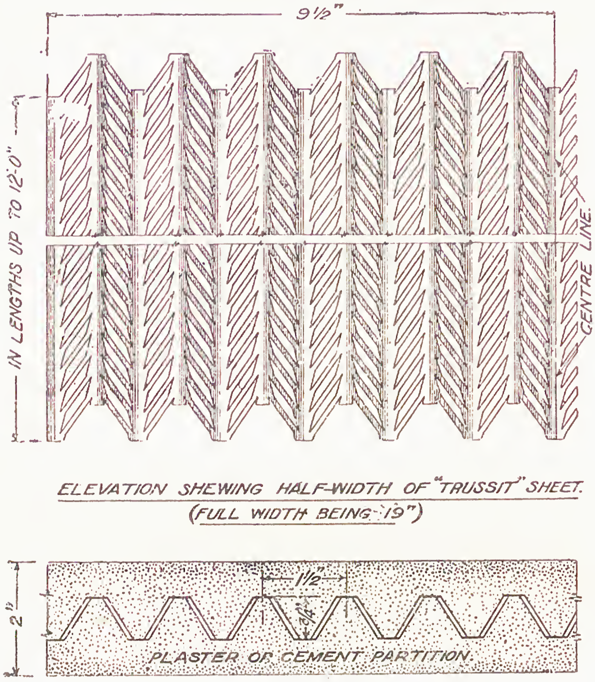


Fig. 179.—"Trussit."

first is made from the best-quality steel sheets stamped out into a serrated pattern, and the makers claim that owing to the rigid stiffening ribs less framing is required in the body of the building. Like the other forms already described, this type of reinforcement, though used largely for partitions, forms a very valuable reinforcement for floor work. It is also supplied in curved forms for use as already described, fitting between the lower flanges of rolled steel joists, thus making arched reinforcement for floors. It is supplied in all lengths up to 12 feet, of standard width $7\frac{1}{2}$ inches. The outer ribs are formed to interlock, enabling any desired width to be obtained. It is supplied in three gauges, 28, 26, and 24. This form of expanded metal reinforcement also does away with the necessity for shuttering and the concrete passing through the perforation affords on the under surface of the floor a good rough key for plastering to.

When used in walls, owing to the strength contributed by the ribs, the thickness of the completed wall is not required to be more than 2 inches.

The second form, "Jhilmil," is of a similar nature but different pattern, being made in sheets 72 × 24 inches and 72 × 18 inches. The major use for this type is for partition work, it being claimed that the perforations in the material are so designed that the minimum of plaster passes through, thus resulting in a saving in the amount of plaster required. It is particularly useful for wrapping round girders and columns, for bridging over spaces in ceilings, and, as has been said, for partitions.

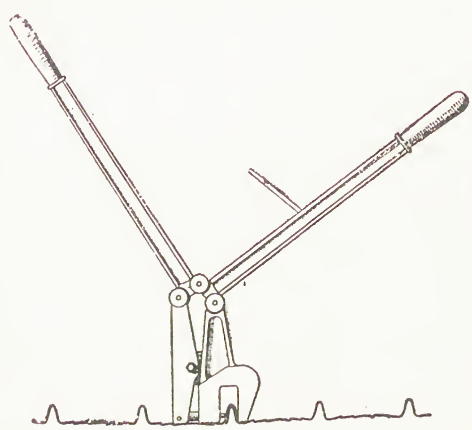


Fig. 180.—Method of punching "Self-Sentering."

Of the wire-mesh fabrics, other forms are "*The B.R.C. Fabric,*" manufactured by the British Reinforced Concrete Engineering Co., Ltd. This is a mesh, oblong or square, of steel wire, supplied in rolls or sheets for reinforcing concrete. The wire used is of hard drawn steel complying with the British Standard Specification for reinforcing concrete. The main wires of the fabric are held rigidly at the correct spacing by transverse wires that are electrically welded to them. The wire is of hard drawn steel, having a breaking strength of 83,000 pounds to 94,000 pounds per square inch, and an average yield of 75,000 pounds. The safe tensile strength may be taken at from 75,000 pounds per square inch.

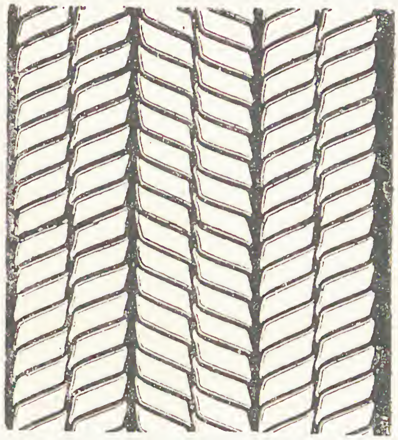


Fig. 181.—Double herringbone mesh "Self-Sentering."

"*B.R.C. Fabric*" is mainly used for floors, roofs, foundations, and roads.

An additional advantage in the use of this type of reinforcement is that once placed it retains its position during concreting.

A form of the fabric is known as "*Weldmesh,*" in which the wires, being welded together into a rectangular mesh and thus requiring no loops or clips, render the material convenient for handling; also the fact that it can be obtained in large units either in rolls or sheets which can be cut either before delivery or on the job to any shape required, without any danger of loosening any of the wires or impairing the rigidity of the wires, is a further advantage, whereas in meshes which are woven, knotted, or attached by loops there must be a certain amount of movement in the wire. This causes deterioration in time at the joints. The standard widths are 81 inches and 61 inches. Where required, this mesh can be supplied galvanised after manufacture, and when so treated it is practically indestructible.

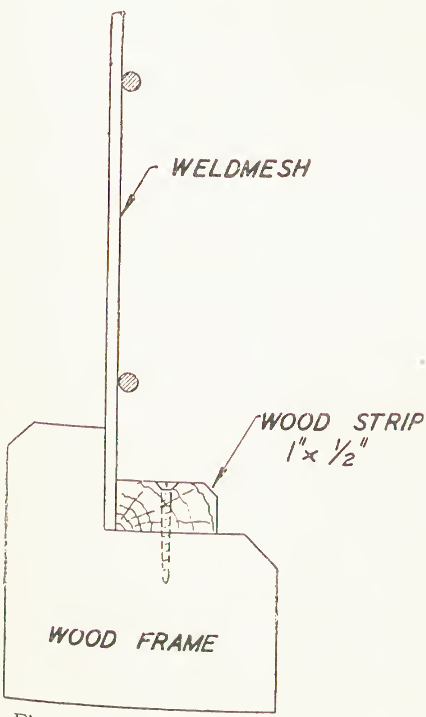


Fig. 182.—Fixing "Weldmesh" in wood frame.

For use in attachment in wood framing the staples are driven in 15 inches apart over those wires which come against the framing, or the wood frame may be rebated and the mesh fixed thereto by screwing wood strips 1 × ½ inch into the rebate.

When attached to steel framing, of

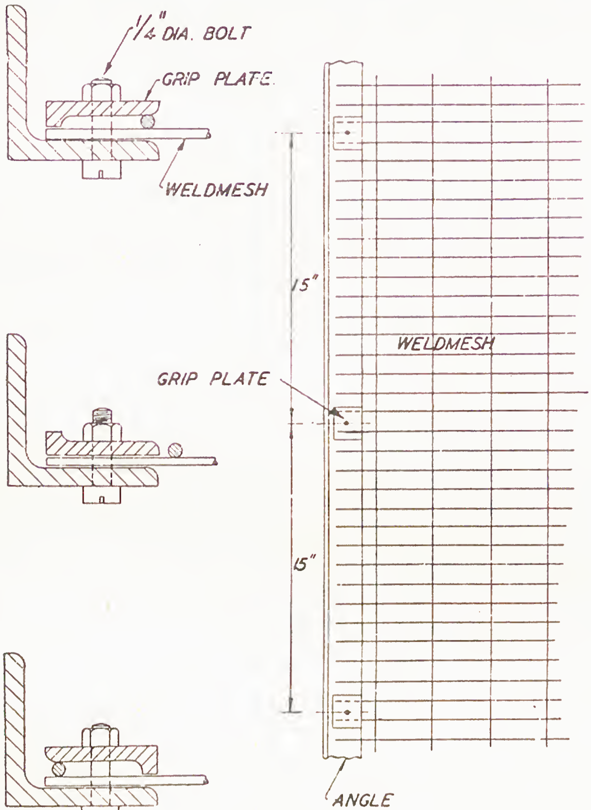


Fig. 183.—"Weldmesh" details. (*By courtesy of the British Reinforced Concrete Co., Ltd.*)

angle or "T" section, the mesh is housed behind the flange of the angle or "T" and attached by ¼-inch bolts at 15-inch centres, and a light grip plate is provided at the back of the mesh under the nut to the bolt. An alternative method of attaching to metal framing is to fasten over the end of the mesh "U"-shaped strips of sheet metal connected to the frame with gusset plates about 3 feet apart. Where the steel framing is of circular section the mesh is clipped to it by means of straps passing around the frame and bolted to the mesh.

A double-layer fabric reinforcement, "*Barmesh*," manufactured by the Indented Bar & Concrete Manufacturing Co., Ltd., is constructed on the job. It can be obtained in either single or double layer and of any weight per super yard and of any spacing. The top layer is rigidly supported in position so that the placing of the concrete can be completed in one operation. This type of reinforcement is mainly used for roads, and in such work it is of interest to note that the reinforcement alone before the concrete is placed is strong enough to support men walking on it.

The same company also supply an "indented"

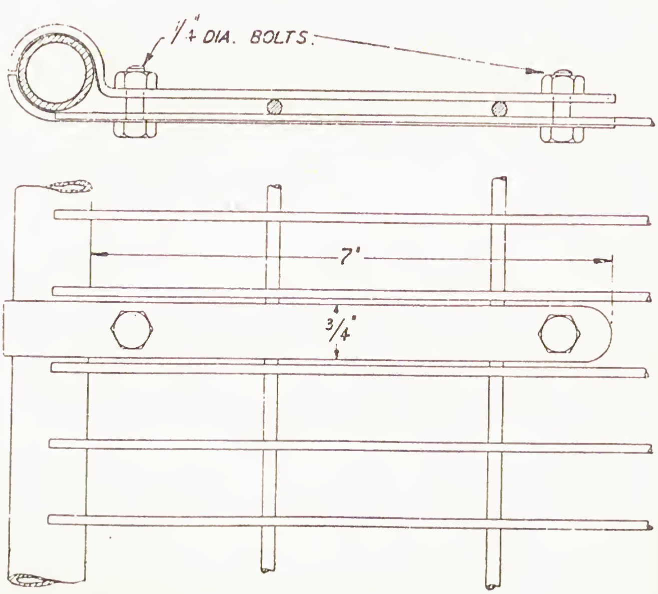


Fig. 184.—"Weldmesh" details.

bar for reinforcement. This is a round bar with a rib running down either side and alternate ribs running round the circumference on top and bottom. It is claimed that the weight per foot of these bars is about the same as the smooth round bars, but the indentations formed between the ribs add considerably to its strength as a reinforcing material. The bars are rolled of British medium steel having a breaking strength of approximately 90,000 pounds per square inch.

Of other bars used for reinforcement there are the "*Kahn*" *Rib Bar*, having alternate circumferential bars without the longitudinal rib of the "indented" bar, and as with the other provides a mechanical bond in the concrete. It is made of any required length and of all standard sizes from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches in variants of $\frac{1}{8}$ inch.

Another form of bar is the "*Kahn*" *Trussed Bar*. This is of diamond section and has the flanges turned up as wings to form shear members which supply the mechanical bond. The standard sections are of the following sizes and weights :

Size of Bar.	Thickness of Wings	Area.	Weight per Lineal Foot (pounds).
$\frac{1}{2} \times 1\frac{1}{2}$ inches	$\frac{1}{8}$ inch	·41	1·4
$\frac{3}{4} \times 2\frac{5}{16}$ inches	$\frac{3}{16}$ inch	·79	2·7
$1\frac{1}{2} \times 2\frac{1}{2}$ inches	$\frac{1}{4}$ inch	1·41	4·8
$1\frac{3}{4} \times 2\frac{3}{4}$ inches	$\frac{1}{2}$ inch	2·0	6·9

A "T"-shaped bar, having the base of the bar straight and the upright web waved, is manufactured in four sections of the following sizes by Messrs. Homan & Rodgers. Sizes : $2\frac{1}{4} \times 1\frac{1}{4}$ inches, 3×2 inches, $4\frac{1}{2} \times 3$ inches, and 6×4 inches. This is known as the "*Waved Tee Bar.*"

The Walker-Weston Co. manufacture double-layer mesh used extensively for road reinforcement. This is supplied in three types : A, B, and C.

Type A, the double-layer interlocked reinforcement, has parallel meshes of 12 inches square interlocked in all directions by diagonal shear members. The tension members are straight and locked by diagonal ties further secured in place by patent wire ties fastened to lower tension members.

Type B, also a double-layer reinforcement, has vertical ties, spacing the two layers apart, the ties being fastened at the intersections of the meshes. It is particularly suitable for reinforcement of thin slabs, whilst the previous reinforcement is suitable for slabs not less than 7 inches thick.

Type C is a single-layer reinforcement composed of rods forming large rectangles, with the space in between filled in with lighter rods forming smaller rectangles, the larger rectangles being six of the smaller rectangles in each direction.

Another form of steel sheeting is manufactured by Messrs. Braby's and known as "*Dovetail*" *Steel Sheeting*. This, owing to its strength and stiffness, serves the double purpose of acting as shuttering and as reinforcement also. When used for floor construction the "Dovetail" sheeting is laid over the supports and fixed into position with special clips. When the supporting beams are widely spaced temporary intermediate supports are required to prevent the "Dovetail" sheets from sagging until the concrete has set. This is effected by running longitudinal timbers under the steel sheeting and supporting them on joists resting on the bottom flanges of the beams. A 24-inch gauge "Dovetail" sheet should carry 4 inches of wet concrete over a span of about 3 feet 6 inches with a deflection of $\frac{1}{4}$ inch without temporary intermediate supports. The "Dovetail" sheeting being non-perforated and lapped at the edges where one sheet joins another, it provides a shuttering which is drip-proof. This is an advantage in building operations as it enables the space below to be used whilst the concrete is being deposited. Further, the concrete is not weakened by the loss of water and cement.

The "Dovetail" sheets can be supplied in any length up to 10 feet and in widths up to 2 feet, and in any gauge from 14 to 30, either black, galvanised, or painted. They are to be obtained shaped, curved, or arched. The width on the section is $\frac{5}{8}$ inch, and the distance from centre to centre of the dovetails is $2\frac{11}{16}$ inches.

When the concrete floor is designed to be continuous over several supports it is necessary to use a mesh reinforcement over the supports to take the tension stresses due to the negative bending which occur at that point, and if the method is adopted of designing the floor as a series of simply supported beams it will be necessary to fix a parting strip over the support. This relieves the concrete of any tension stress, and prevents any tendency of the concrete cracking at that point. The underside of the "Dovetail" sheeting is covered with plaster and the steel beam is enclosed with metal lath and plastered round.

The proportions of the concrete used with "Dovetail" sheets is 1 : 2 : 4, the large aggregate to pass a $\frac{1}{2}$-inch ring. When the concrete has set the underside should be plastered to a thickness of not less than $\frac{3}{8}$ inch under the corrugations. The proportions for this plastering are 1 part of Portland cement to 2 or 3 parts of sand with a little hair. Work the plaster thoroughly into the corrugation so that the steel is completely coated. A plaster easier to apply of the following proportions may be used: 1 part Portland cement, $\frac{1}{2}$ part lime, 3 parts sand, and a little hair.

The weight of slabs reinforced with this sheeting are as follows:

2 inches thick	32 pounds per square foot.
$2\frac{1}{2}$ inches thick	38 pounds per square foot.
3 inches thick	44 pounds per square foot.
$3\frac{1}{2}$ inches thick	50 pounds per square foot.
4 inches thick	56 pounds per square foot.
$4\frac{1}{2}$ inches thick	62 pounds per square foot.
5 inches thick	68 pounds per square foot.

Tests.—The following is a list of tests made on floors constructed with "Dovetail" steel sheeting:

Gauge of Sheet.	Span. Feet.	Width. Inches.	Thickness of Slab from Centre of Steel in Inches.	Concrete Mixture.	Load in Pounds.	Deflection. Inches.
24	6	12	$4\frac{1}{2}$	1 : 2 : 4	7,452 distributed	$\frac{1}{4}$
24	6	12	$\frac{3}{4}$	1 : 2 : 4	720 concentrated	$\frac{7}{8}$
24	8	12	$3\frac{1}{4}$	1 : 3 : 4	6,900 distributed	broke

Methods of Fixing.—The side laps may be fixed by means of a short flat strap fastened by bolts and nuts through the corrugations next to the lap and on either side of it. These straps should be placed at about 2-foot centres along the sheet. An alternative method is to run light steel bars across the corrugation to the full width of the floor, and wiring the steel bars to the sheets at the side laps and at the centre of the sheet. The end laps have the sheets crimped so that one sheet will fit into the other. These laps should be at least 3 inches, and the method is known as the "*Eclipse Patent*."

Patent Reinforced Floors.—Reinforced floors are also constructed by patent methods, in which the component parts are supplied ready for erection on the job.

Of these, the "*Siegwart*" *Fireproof Floor* is a well-known example. This consists of "Siegwart" beams already constructed of the required length to lay in between the main beams after the bottom flange of the beam has been encased in concrete to provide a bearing for the "Siegwart" beams. The ends of the "Siegwart" beams are rebated to fit under the top flange, and a special reinforcement is incorporated in the material of the beam, though the beam itself is hollow, which two factors contribute strength, together with lightness, and economy of materials. The beams are designed on the elastic theory, whilst the materials are used to the utmost advantage so as to provide in the lightest sections possible for bending movement and shear, and a factor of safety of four is given. No centering is required, and no temporary supports are needed to lay them, the beams simply requiring to be lifted and put into the positions for which they are fitted. It is stated by the makers that all the beams are made of the same unvarying materials under the same conditions and with skilled supervision. Results are checked by regular tests, with the result that the hollow provides a resistance to temperature changes, and the conductivity of the beams, together with the porous nature of the surfaces, prevent condensation, whilst both the hollow space and the porous surfaces offer a resistance to sound transmission.

A similar form of beam is used in roof construction as on steel buildings where fire-resistance is required.

The beams are laid at right angles to the principals and ridges, and gutters are formed of pre-cast concrete slabs. The under surface of the "Siegwart" beams provide a smooth surface, suitable for lime washings direct if this is desired. These beams are also used in the construction of step galleries for cinemas and theatres. The method of construction is to bolt angle cleats to the raking joists of the roof to hold in position pre-cast concrete packings of the required triangular shape after the manner

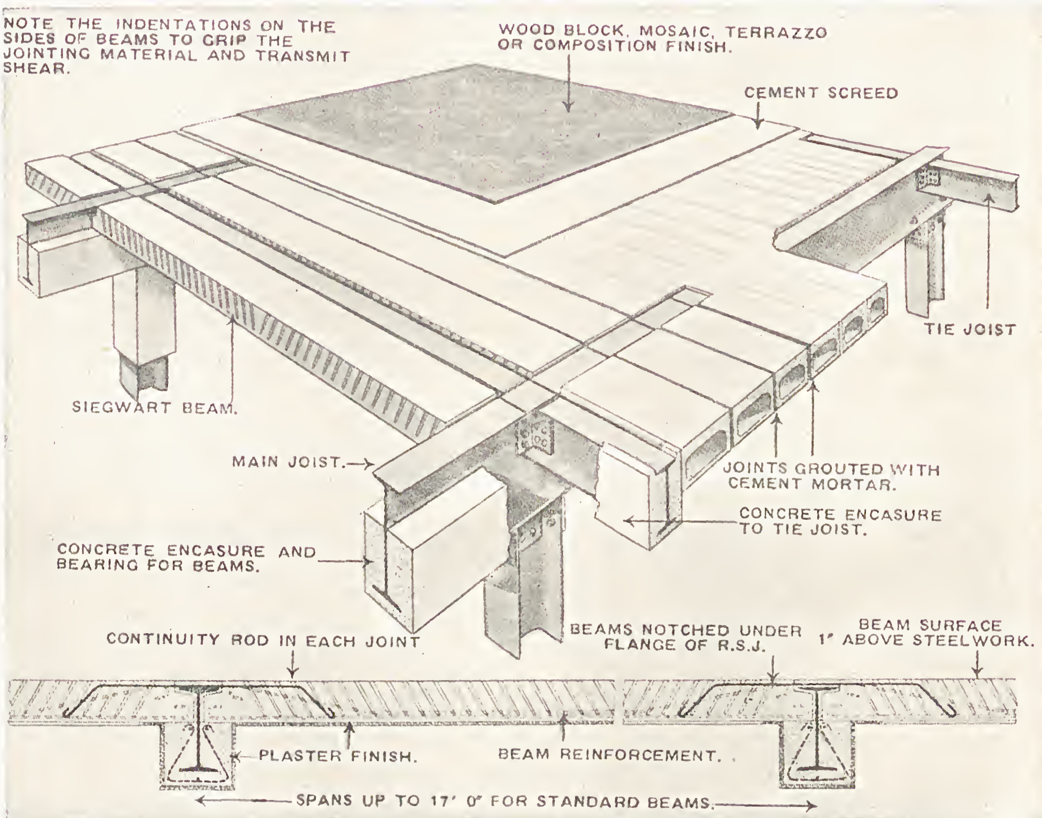


Fig. 185.—"Siegwart" fireproof floor. (*By courtesy of the Siegwart Fireproof Floor Co., Ltd.*)

of the carriages used in stair making to carry the ends of the "Siegwart" beams, and thus to form level step surfaces.

The "*Siegwart*" *roofs* may be bored after the beams are laid to admit the passage of service pipes and conduits, and all light ceiling fixtures may be fastened to the beam soffits with Rawlplugs.

To fix floor boards the following methods may be employed: "Bulldog Patent Clips" are pressed into the joints immediately after grouting, and these carry the battens to which the flooring is nailed, or, alternatively, $\frac{1}{2}$-inch bolts are grouted into every sixth joint, these bolts securing the battens by means of a nut and washer.

Where trimming is required in the span for openings, the ends of the

" Siegwart " beams cut to form the opening are carried with special wrought-iron straps which rest on at least two continuous beams on each side of the opening and are bent down to carry the underside of the trimmed beams.

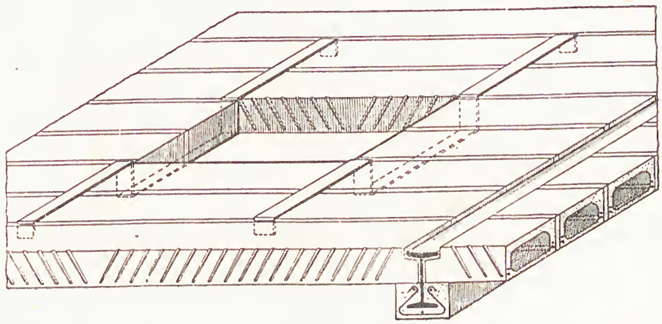


Fig. 186.—Opening in " Seigwart " floor.

Another well-known form of patent floor is that known as the " *Caxton Floor*," supplied by Caxton Floors, Ltd. This floor consists of Caxton Patent Hollow Tiles in combination with reinforcing rods set alternately in concrete. The cross-section to a typical Caxton floor shows a series of haunched " T " beams.

In floors constructed so that the reinforcement passes from one panel to another across the bearings, the greatest compressional stresses lie in the lower portions of the slab, adjacent to the bearings, and to overcome this difficulty in connection with the Tee beam for continuous work, the " *Caxton Hollow Tile* " is so constructed that it can be built in in the inverted position with the result that the vital compressional area is doubled. The method of construction of these floors is that they are assembled on the job, on temporary timber centering which is provided and erected by the manufacturers.

The continuous reinforcement rods are laid in over the supports and the tension reinforcement rods are laid in on the centering with the patent hollow tiling in between the rods. The concrete is then placed between and over the hollow tiles, being well worked into the set-backs of the tiles and round the steel reinforcing rods. The surface of the concrete is finished with a spade or rough screed face, sufficient thickness of concrete cover being laid over the hollow tile to comply with the district fireproofing regulations.

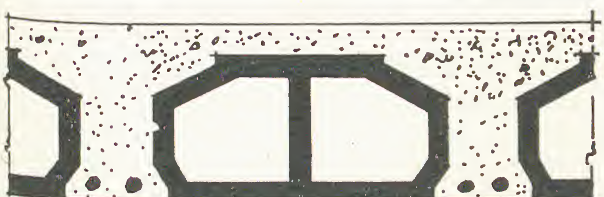


Fig 187.—Caxton floor. (*By courtesy of Messrs. Caxton Floors, Ltd.*)

Any of the usual finishes can be employed, fixing blocks or metal clips being inserted in the concrete as it is poured and as required. If wood blocks, marble, or other surfacing is called for, a final screed will be required to be executed by the general contractor.

For use in roofs, concrete is required only to fill in between these hollow tiles, but not over the tops.

The "*Truscon Floor*," manufactured by the Trussed Concrete Steel Co., Ltd., is a form of flooring consisting of beams and slabs cast in concrete in one continuous operation. The beams are formed at 2-foot centres, over specially made "Truscon" troughs, which are placed on bearers supported by standards carrying 4 × 3-inch transverse bearers. The standard trough is inverted on to the 7 × 2-inch bearers and kept in position by 2 × 1-inch runners. The size of the trough is 1 foot 10 inches span and 28 inches in length. The troughs may be removed after two or three days, and when the concrete floor has set the timber bearers may also be removed. Where a flat ceiling is required "Hy-rib" lath is attached to the underside of the beams for plastering. The space provided between the beams and the floor and ceiling thus provided is found of exceptional value in modern construction for forming concealed conduits for pipes, wires, etc., which now enter so much more into the construction of modern hospitals, hotels, office buildings, flats, etc. This space also acts as a sound insulator, which quality may be increased by inserting a surface of pumice bound with tar mastic on the top of the "Truscon" slab, laid in Cabots quilt over this, and underneath the floor building.

Fig. 188.—Caxton floor. Hollow tile reversed.

Or, alternatively, if it is necessary that the ceiling be suspended some distance below the floor by means of wood hangers the metal clips may be wrapped with felt as a precaution against the transmission of vibration.

The nature of this type of flooring also lends itself to the formation of drainage channels, such as are required in laboratories and factories, within the thickness of the floor by widening of any one of the beams and the insertion of a gutter therein. Also the new system of lighting by panels may be fitted conveniently in the spaces formed by the troughs between the beams. The same remarks apply to heating by the panel system.

The proportions and mixing of the concrete recommended are the same as for other floors, and of the reinforcing steel the makers require that it is to be of quality "A" as defined in the British Standard Specification No. 15, or to be clean and free from oil and dirt, a slight film of rust being allowable, provided that all loose scale is removed. No bar shall be welded unless consent is obtained from the architect or engineer to the company. The bending of the steel is to be carried out cold, and the placing is to be carried out in accordance with the detail drawing supplied by the manufacturers.

It is important with this floor, as with all other concrete work, that

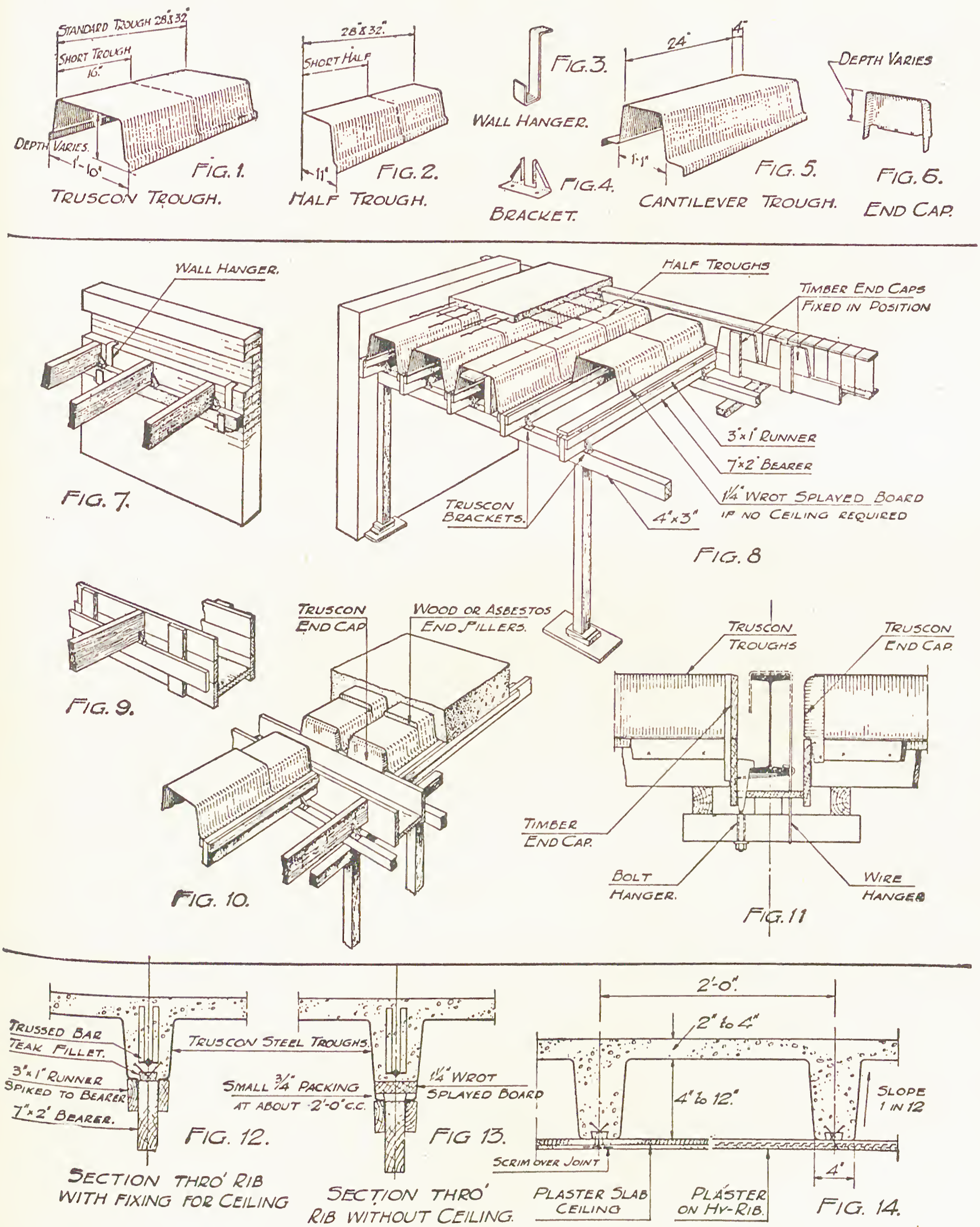


Fig. 189.—The "Truscon" floor. (*By courtesy of the Trussed Concrete Steel Co., Ltd.*)

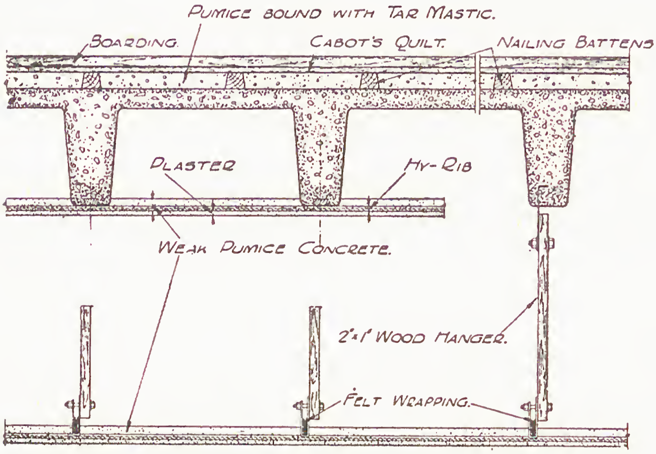


Fig. 190.—" Truscon " floor with suspended ceiling.

prior to the placing of the concrete, all formwork should be cleaned and washed with water.

In placing the concrete a point is made that it shall first be discharged on to a spot board and then transferred to the work with shovels. This enables the steelwork to be thoroughly surrounded, and as a further precaution to ensure that no voids shall be left the concrete should be well worked in, and the reinforcing steel may be slightly vibrated, whilst the concrete is still mastic.

Positions of stops will be found to be marked on the drawings, and these should come in the centre of spans of beams and slabs and at right angles to the direction of the main reinforcement. The centering to form the stop should be firmly fixed and scribed round the reinforcement steel. If any concrete flows past the stop it must be hacked off as soon as the concrete has set. Before any new concrete is placed against the stopped face, the concrete previously placed shall be hacked and scoured with a wire brush to remove the scum. The joints should then be washed with water and covered with a creamy cement grout. Care should be taken in casting the second half of the stop member not to lift the reinforcing steel and crack the concrete previously placed.

A further system of reinforced concrete floor is that known as the " *Coignet.*" In this a top reinforcement is used, a beam being calculated as a Tee. The beam is reinforced by four rods tied together with wire hangers and the slab with continuous reinforcing rods at right angles in two layers.

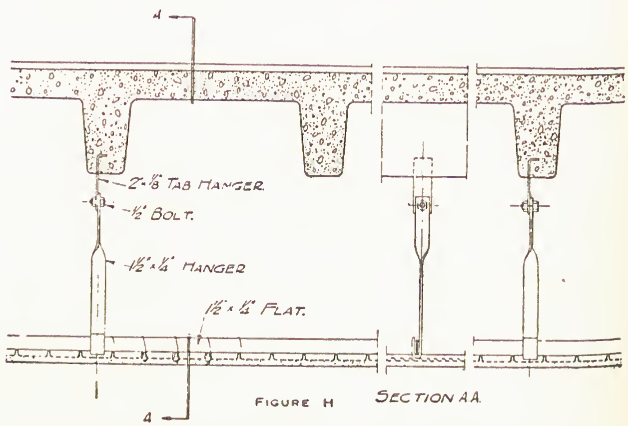


Fig. 191.—Alternative method of above

In a reinforced concrete floor designed by the Fawcett Construction Co., known as " *Monlithcrete* " *System,* the slab is cast in one piece between the main beams, the beams themselves being cast in concrete, a steel girder being set in the centre of a concrete beam.

Of the floors constructed with hollow bricks, the " *Kleine* " *Floor* is one of the oldest and most suitable for wide spans, where a saving in dead load is desired. Reinforcement is introduced into the cement mortar or the cement concrete joints consist either of mild steel hooks or rods.

Another combination of hollow tile and concrete is that known as the " *Bison* " *Floor* designed by Concrete, Ltd. This consists of pre-cast

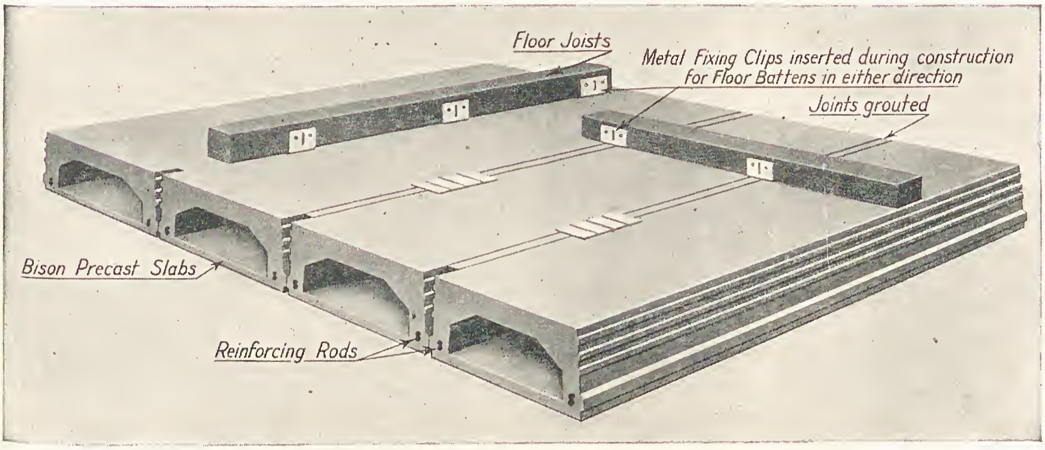


Fig 192.—" Bison " flooring. (*By courtesy of Messrs. Concrete, Ltd.*)

hollow concrete slabs, composed of 4 parts of washed and graded ballast, 2 parts of washed sharp sand, and 1 part of Earle's " Pelican," or ferrocrete cement, in combination with reinforcing rods let into the underside of the tile units. Both ends of the unit have at least 9 inches of solid concrete to form an adequate anchorage for the hooked ends of the bars and to act as a compressive pad in the negative bending movement. When placed side by side on the steelwork the spaces between are grouted up.

The " *Bison* " *Tile Floor* is an alternative floor by the same company in which the tile is designed to offer a tile soffit rather than a concrete soffit. These units are also used in different dimensions for forming the steps in theatre galleries when they consist of treads and risers, resting on small intermediate steel joists spanning from raker to raker.

Pre-cast raking floors are also formed of these units, run from rolled steel joist raker to rolled steel joist raker, the steps being formed over the pre-cast hollow flooring in breezed concrete.

" *The King* " *Self-centering Flooring System* is formed of an interlocked floor tube in tile, designed for fitting without cement grout and running between the joists at centres not exceeding 3 feet. Over these hollow tubes is run in a covering of cement concrete to form a flush-topped surface. The ends of the tubes are slotted to fit over the bottom flanges of the filler joists in such a manner that the tile work of the tube affords a covering to the underfacing of the flange of an inch thick.

STAIRCASES

Reinforced concrete stairs are formed in either of the following ways :

1. Where the treads and risers are cantilevered from the side walls, in which case the strength of the side walls to resist the cantilever strain must be carefully calculated.
2. As inclined slabs, in which the reinforcement is continuous from beam to beam ; and
3. Concrete stringers, in which the stringers are designed as beams.
4. Steel angles bolted to steel stringers, on which the steps are formed of concrete reinforced with expanded metal.

Stairs formed of concrete are essential in a building of the type known as Fireproof. Concrete being a poor conductor offers a very considerable resistance to fire, and is often a powerful aid in resisting the spread of conflagration. In a very severe fire, however, the heat is intense and prolonged, and upon the nature and quality of the aggregate depends to a great extent the resistance offered by the concrete and the extent of the resultant damage. Slag and breeze will heat rapidly, expand, and disintegrate, and gravel, subjected to a high temperature, will explode. When a fire has got well hold of a building, the metal reinforcement becomes a source of increased destruction, as the rates of expansion of steel and concrete, though varying very slightly under moderate changes of temperature, under a high temperature are not equal. The resistance to fire of concrete has been dealt with by Mr. R. E. Stradling, the Director of the Building Research Board. A series of experiments carried out under his supervision proves that a good Portland cement mortar, when exposed to heat up to 98° C., expanded, but at 100° C. the cement mortar contracted and usually failed. Between 100° C. and 300° C. it went to pieces. Concrete, whilst it expanded up to about 90° C., contracted above that temperature. But the steel above that temperature continued to expand and so rupture followed.

The proportioning of the ingredients of concrete also had a decided influence on this matter ; thus a 1 to 1 mixture of Portland cement and Leighton Buzzard sand with 12·67 per cent. water gained in strength when exposed to heat from 97° C. to 360° C., while a 1 to 2 mixture with 9·5 per cent. water ceased to gain strength above 280° C. ; and a 1 to 3 mixture with 8 per cent. water failed to gain strength after passing 97° C.

It was also made clear that great heat had a beneficial effect on quartz sand, proving that hard red brick, basalt, dolerite, and similar stones form good fire-resisting aggregates. Thus a 1 : 2 : 4 red-brick concrete, with a strength of 3,500 pounds per square inch at 28 days, gained 11·5 per cent. when heated to 200° C., and 18·85 per cent. when heated to 300° C. ; after passing 600° C. it showed a loss in strength.

These experiments show that, whereas after the test the concrete might appear as sound as before, subsequently the destructive effect of the heat was to be seen in the concrete crumbling to pieces.

THE SURFACING OF CONCRETE FLOORS, STEPS, Etc.

The surface of concrete floors requires further treatment before they are ready for use in a building, as it is only in rough basements that a screeded concrete surface would be found satisfactory.

Granolithic.—Granolithic surfacing may be laid in the following ways:

1. Either as a topping at the time of the construction of the floor, immediately after the base has been constructed, in which case the base must be terminated 1 inch below the finished level required; or
2. The base allowed to set, and the topping laid in at a later date.

The disadvantage of the former method is that great care has to be taken of the finished surface, so that it may not be damaged during the subsequent building operations; whereas

In the second method the topping is not added until the heavier construction is finished and the roof and floors covered over.

A newly laid granolithic surface should not be used until at least five days after it has been laid, and it would be better after that time if it should be covered with sawdust which is kept moist.

The mortar which is used in the granolithic finish coat is composed of 1 part cement to 2 parts of aggregate.

And in the first method, which is known as the integral method, any excess of water flushing to the surface should be removed, and the granolithic mixture should be spread evenly and straightedged, the surface being worked over, compacted, and levelled with floats before the initial set takes place.

In the second method the base concrete must be washed free from dust and sand, thoroughly soaked with water to prevent undue absorption, and grouted with a creamy cement grout. The granolithic is then floated over the grout and trowelled with steel trowels. All trowelling must cease before the final set has taken place. The finished floor must be protected against the weather for at least twelve hours after the final set.

Faults in granolithic which generally cause dusting from the surface are often due to wrong proportioning; too much cement being used, too dry a mix, which makes a porous floor; also too wet a mix, the incorporation of dryers to the surface; and too much trowelling.

For hardening concrete floors silicate of soda can be used or one of the following proprietary materials:

"Alundum" Tile.—In solid floors, the nosing of a stair tread frequently becomes very smooth and slippery with use, and for this purpose a patent stair tile is used at the nosing, and is known as an "*Alundum*" *Tile.* Alundum is an abrasive which has been used for many years in the manufacture of grinding wheels, polishing grain, rubbing stones, and similar products. It is made by firing the mineral bauxite in electric furnaces at a temperature of 3,700° Fahr., and in chemical composition it is the same as the ruby or sapphire. An unusual combination of extreme hardness and extreme toughness gives it remarkable qualities for resisting wear. In the manufacture of " Alundum " tiles, the abrasive is bonded with a small percentage of clay turned into moulds of standard shapes and sizes, and kiln baked. The result is a material which is permanently non-slip, and which is not affected by oil or water. Grooves and corru-

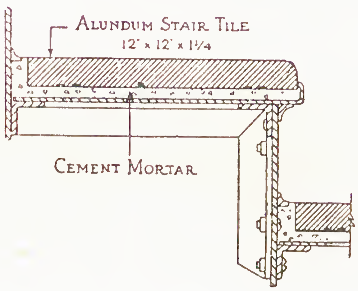


Fig. 193A.

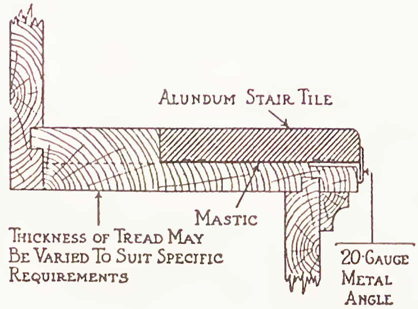


Fig. 193B.

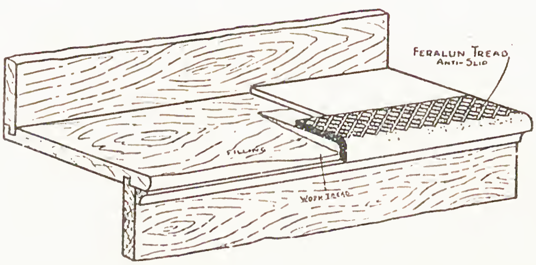


Fig. 193C.—The " Alundum " tile nosing. (*By courtesy of Messrs. Adamite Co., Ltd.*)

gations are not necessary, and as these may be the cause of tripping, this is an additional advantage. The result is a tile that will withstand the most severe traffic conditions, and as the grains of the abrasive are held together by the bond of vitrified clay, a non-resonant structure is formed which produces a quietness, and footfalls are not to be heard in the manner customary with stone paving or ordinary tile flooring.

" Ironite."—Another non-slip and hardening material for use with Portland cement is known as " *Ironite.*" This will provide a floor topping that will not cut up or become dusty even when subjected to the heaviest traffic, and is also impervious to water and grease.

The method recommended for laying is to cover a base of good concrete with 1–1½ inches of granolithic, including ½ inch " Ironite " topping. The latter is to be laid as a final and separate operation, and to consist of 20 pounds of "Ironite" to every 100 pounds of Portland cement, to be thoroughly mixed whilst dry, and to this add 2 parts by bulk of clean crushed granite or sharp clean sand. About 3½ pounds of "Ironite" are required per square yard.

Test.—An attrition test gave the following results:

Two concrete blocks were made up in the Laboratory composed of 2 parts of granite chippings to 1 part of Portland cement. In addition 20 per cent. "Ironite" by weight of the cement was added to the mix of block No. 2. These blocks were submitted to an attrition test in the Laboratory with the following result:

Block No	Composition.	Mean Thickness Rubbed Away.	Loss in Weight.
		Inch.	Per cent.
1	2 parts granite chippings, 1 part Portland cement	0·245	4·09
2	2 parts granite chippings, 1 part Portland cement, plus 20 per cent. "Ironite" by weight of Portland cement	0·078	1·30

The age of the blocks was twenty-eight days, the area of the rubbing face 36 square inches, the duration of the test one hour, the distance rubbed through 5 miles, and the pressure on the rubbing face 0·75 pound per square inch.

"Carborundum."—Another form of non-slip surfacing of high reputation is known as "*Carborundum.*" This is prepared in a special form of grain, and used in the following manner:

After the first or foundation layer of concrete has been spread a finish layer of about 1 inch in thickness is laid. This is allowed to reach an initial set. With the finish layer in this condition the "Carborundum" grains are sprinkled on the smooth surface and worked into it by means of a wood float. Where the special "Carborundum" C.C. grains are used, for floor surfacing, it has been found that about a No. 12 mesh hand screen provides a satisfactory means of distributing the "Carborundum" grains evenly over the floor surface. The most satisfactory results are to be obtained with a ¼ pound C.C. grain to the square foot of floor surface. If it is required to impregnate with "Carborundum" to a thickness of ⅜–½ inch, from 5 pounds to 7 pounds per square yard of "Carborundum" will be required.

"Duromit" is another hardening non-slip surfacing supplied by the Kleine Co., Ltd., and the claim is made for it that it is second in hardness only to diamonds. The fact that the "Duromit" aggregate is practically all of the same specific gravity and is carefully graded, the largest particles in about 20 grades passing a $\frac{1}{12}$-inch mesh, ensures not only an extraordinarily dense surface but a uniformly hard one. "Duromit"

can be laid on the work, or is supplied in the shape of tiles, and when combined with colour, pleasing effects can be obtained.

For ordinary purposes an ordinary " Duromit " surface floor should be $1\frac{1}{2}$ inches thick, consisting of a $1\frac{1}{2}$-inch " Duromit " surface, on a $1\frac{1}{8}$-inch cement and sand screeding, the latter being laid direct on to the concrete base. The tiles are 1 inch thick in the sizes of 12×12 inches, 9×9 inches, or 6×6 inches, in seven different shades of colour.

CHAPTER 10

REGULATIONS GOVERNING REINFORCED CONCRETE

From the London County Council's "London Building (Constructional) By-laws, 1952."

PART VII.—THE STRUCTURAL USE OF REINFORCED CONCRETE

7.01. ***Reinforcement.***—(1) Reinforcement shall be free from loose mill scale, loose rust, oil or other matter which might affect adversely the proper function of reinforcement with concrete.

(2) For the purposes of by-laws 7.02, 7.10 and 7.11, where a reinforcement

(*a*) is not round; or

(*b*) consists of two bars twisted together;

the diameter of that reinforcement shall be deemed to be the diameter of a circle having an area equal to the area of the cross-section of that reinforcement.

7.02. ***Cover of Reinforcement.***—(1) Subject to the provisions of Part IX of these by-laws, the minimum thickness of concrete cover to reinforcement (exclusive of plaster, rendering or other applied covering or decorative finish) shall be:

(*a*) for each end of a reinforcement, not less than 1 inch, or twice the diameter of that reinforcement, whichever is the greater;

(*b*) for a longitudinal reinforcement in a column, not less than 1½ inches or the diameter of that reinforcement, whichever is the greater:

provided that, where a column has a least lateral dimension of 7½ inches or less with longitudinal reinforcements each not exceeding ½ inch in diameter, the minimum thickness of concrete cover shall be not less than 1 inch;

(*c*) for a main reinforcement in a beam, not less than 1 inch or the diameter of that reinforcement, whichever is the greater;

(*d*) for tensile, compressive, shear, or other reinforcement in a slab, not less than ½ inch or the diameter of that reinforcement, whichever is the greater;

(*e*) for any other reinforcement, not less than ½ inch or the diameter of that reinforcement, whichever is the greater.

(2) Where reinforced concrete is exposed to the weather, the minimum thickness of concrete cover to reinforcement specified in paragraph (1) of this by-law shall be increased by not less than ½ inch.

(3) Notwithstanding the provisions of paragraphs (1) and (2) of this by-law, the concrete cover to reinforcement in precast factory-made reinforced concrete units shall be not less than 1 inch.

(4) Where reinforced concrete (other than reinforced concrete piling) is in contact with earth, the minimum thickness of concrete cover to reinforcement shall be not less than 3 inches unless special precautions to the satisfaction of the district surveyor are taken to prevent corrosion of that reinforcement.

7.03. ***Stresses in Concrete in Reinforced Concrete.***—(1) Subject to the provisions of by-laws 7.05 and 7.07, the compressive, shear and bond stresses in concrete in reinforced concrete shall not exceed the maximum permissible stresses specified in Table XXII for the designation of concrete specified in that Table.

TABLE XXII

MAXIMUM PERMISSIBLE STRESSES IN CONCRETE IN REINFORCED CONCRETE, IN LB. PER SQUARE INCH

Designation of concrete.	Compression.		Shear.	Average bond.	Local bond.
	Due to bending.	Direct.			
Grade I	975	780	100	125	190
Grade II	850	680	85	110	165
Grade III	750	600	75	100	150
Grade IA	1,500	1,140	130	150	220
Grade IIA	1,250	950	115	135	200
Grade IIIA	1,000	760	100	120	180

Where the proportions of fine to coarse aggregate are different from those of the Grades of concrete specified in this Table, the maximum permissible stresses shall be based on the ratio of the sum of the volumes of fine and coarse aggregate, each measured separately, to the volume of cement, and shall be obtained by proportion from the two nearest Grades of concrete.

(2) The stresses on high alumina cement concrete in reinforced concrete shall not exceed the maximum permissible stresses specified in Table XXII for Grade IA concrete.

(3) The maximum permissible stresses on concrete in compression specified in the preceding paragraphs of this by-law may be increased by 10 per cent. where the concrete is to the satisfaction of the district surveyor vibrated by means satisfactory to him, whereupon the resistances to crushing specified for the concrete in Tables V, VI or VII shall be increased by 10 per cent.

(4) Where the length L of a beam, between adequate lateral restraints, exceeds 20 times the breadth B of its compression flange, the compressive stress in the concrete shall not exceed the maximum permissible compressive stress specified in Table XXII multiplied by the coefficient specified in Table XXIII for the slenderness ratio L/B specified in that Table.

TABLE XXIII

STRESS REDUCTION COEFFICIENTS FOR SLENDER BEAMS

Slenderness ratio L/B . .	20	30	40	50	60
Coefficient	1·00	0·75	0·50	0·25	0

The coefficient for intermediate values of the slenderness ratio shall be obtained by linear interpolation.

7.04. *Stresses in Reinforcement in Reinforced Concrete.*—(1) Subject to the provisions of by-law 7.05, the tensile and compressive stresses in reinforcement in reinforced concrete shall not exceed the maximum permissible stresses specified in Table XXIV for the kind of stress specified in that Table.

(2) For the purpose of this Part of these by-laws, the modular ratio shall be assumed to be equal to 15.

7.05. *Stresses in Reinforced Concrete Columns.*—(1) Where a reinforced concrete column or part thereof has a ratio of effective column length to least lateral dimension not exceeding 15, the stresses in that column or part shall not exceed the maximum permissible stresses specified in by-laws 7.03 and 7.04.

(2) Where a reinforced concrete column or part thereof has a ratio of effective column length to least lateral dimension exceeding 15 and not exceeding 36, the stresses in that column or part shall not exceed the maximum permissible stresses specified in by-laws

TABLE XXIV

MAXIMUM PERMISSIBLE STRESSES IN REINFORCEMENT IN REINFORCED CONCRETE

Kind of stress.	Maximum permissible stresses in reinforcement in reinforced concrete in lb. per square inch.	
	Mild steel complying with B.S. 785 : 1938.	Steel with minimum yield point (f_y lb. per square inch).
Tension in helical reinforcement in a column . .	13,500	0·35 f_y or 18,000, whichever be the lesser.
Tension other than tension in helical reinforcement in a column or in shear reinforcement	18,000	·5 f_y or 27,000, whichever be the lesser.
Tension in shear reinforcement in beams . . .	18,000	·5 f_y or 20,000, whichever be the lesser.
Compression in longitudinal reinforcements (other than twin-twisted bars)		
(*a*) in axially-loaded columns . . .	18,000	·5 f_y or 20,000, which ever be the lesser.
(*b*) in columns other than axially-loaded columns	The calculated compressive stress in the surrounding concrete multiplied by the modular ratio.	
Compression in main reinforcements (other than twin-twisted bars) in a beam or slab when the compressive resistance of the concrete is not taken into account	18,000	·5 f_y or 20,000, whichever be the lesser.
Compression in main reinforcements (other than twin-twisted bars) in a beam or slab where the compressive resistance of the concrete is taken into account .	The calculated compressive stress in the surrounding concrete multiplied by the modular ratio	

7.03 and 7.04, multiplied by the coefficient specified in Table XXV for the ratio specified in that Table.

(3) The stress in a column due to a combination of direct load and bending action shall not exceed the maximum permissible stress for bending specified in by-laws 7.03 and 7.04 multiplied by the coefficient specified in Table XXV for the ratio specified in that Table.

TABLE XXV

STRESS REDUCTON COEFFICIENTS FOR SLENDER COLUMNS

Ratio of effective column length to least lateral dimension.	Coefficient.
15	1·0
18	·9
21	·8
24	·7
27	·6
30	·5
33	·4
36	·3

The coefficient for intermediate ratios of effective column length to least lateral dimension shall be determined by interpolation.

(4) The ratio of effective column length to least lateral dimension for any reinforced concrete column or strut shall not exceed 36.

7.06. *Effective Length of Reinforced Concrete Columns.*—For the purposes of by-laws 7.03, 7.04 and 7.05, the effective column length of a reinforced concrete column shall be that specified in Table XXVI for the type of column specified in that Table.

TABLE XXVI

EFFECTIVE COLUMN LENGTH OF REINFORCED CONCRETE COLUMNS

Type of column.	Effective column length where L = the length of the column between centres of restraining members.
Properly restrained at both ends in position and direction	·7L
Properly restrained at both ends in position and at one end in direction	·85L
Properly restrained at both ends in position but not in direction	L
Properly restrained at one end in position and direction and at the other end partially restrained in direction but not in position	1·5L
Properly restrained at one end in position and direction but not restrained at the other end . . .	2·0L

Where a column is of a type not specified in this Table, the effective column length of that column shall be determined to the satisfaction of the district surveyor.

7.07. *Stresses Due to Wind.*—The maximum permissible stresses specified in by-laws 7.03, 7.04 and 7.05 may be increased by $33\frac{1}{3}$ per cent. when the calculations are based on all loads including wind load

provided that

(i) the said stresses are not exceeded when the calculations are based on all loads other than wind load;

(ii) the maximum permissible stress in reinforcement shall not exceed 27,000 lb. per square inch.

7.08. *Longitudinal Reinforcement for Columns.*—(1) The aggregate cross-sectional area of the longitudinal reinforcements in a reinforced concrete column shall be not less than 0·8 per cent. nor more than 8 per cent. of the gross cross-sectional area of that column required to transmit all the load.

(2) A reinforced concrete column having helical reinforcement shall have not less than six longitudinal reinforcements, placed equidistantly around the inner circumference of, and in contact with, that helical reinforcement.

(3) At each splice in a longitudinal reinforcement, the spliced reinforcements shall overlap longitudinally through a distance of not less than twenty-four times the diameter of the smaller reinforcement, or a sufficient distance to develop the force in the reinforcement by bond, whichever is the greater dimension.

7.09. *Transverse or Helical Reinforcement for Columns.*—(1) A reinforced concrete column shall have transverse or helical reinforcement so disposed as to provide all necessary restraint against buckling of the longitudinal reinforcements; that transverse or helical reinforcement shall be secured to the longitudinal reinforcements and the ends of that transverse or helical reinforcement shall be anchored properly.

(2) The diameter of transverse reinforcement shall be not less than $\frac{3}{16}$ inch or one-quarter of the diameter of the longitudinal reinforcement, whichever is the greater dimension.

(3) The pitch of transverse reinforcement shall not exceed

(*a*) the least lateral dimension of the column; or

(*b*) 12 times the diameter of the smallest longitudinal reinforcement in that column; or

(*c*) 12 inches;

whichever is the least dimension.

(4) (*a*) Helical reinforcement shall be of regular formation with the turns of the helix spaced evenly.

(*b*) The pitch of the helical turns shall be

(i) not more than 3 inches or one-sixth of the core-diameter of the column, whichever is the lesser dimension, and

(ii) not less than 1 inch or three times the diameter of the helical reinforcement, whichever is the greater dimension.

7.10. ***Diameter of Reinforcement.***—(1) The diameter of a longitudinal reinforcement in a reinforced concrete column shall be not less than $\frac{1}{2}$ inch.

(2) Where the main reinforcement in a reinforced concrete beam or slab consists of a single bar, the diameter of that reinforcement shall be not less than $\frac{1}{4}$ inch, and where that main reinforcement consists of twin bars, the diameter of each bar shall be not less than $\frac{3}{16}$ inch.

(3) The diameter of a reinforcement in reinforced concrete (other than a longitudinal reinforcement in a column or a main reinforcement in a beam or slab) and the diameter of a link, helix, stirrup, or the like, shall be not less than $\frac{3}{16}$ inch.

(4) The diameter or reinforcement forming a mesh-reinforcement for the purpose of resisting tension in reinforced concrete shall be not less than $\frac{1}{8}$ inch.

7.11. ***Spacing of Reinforcement.***—(1) The distance between two reinforcements in reinforced concrete shall be not less than

(*a*) the diameter of either bar if their diameters are equal ; or

(*b*) the diameter of the larger bar if their diameters are unequal ; or

(*c*) $\frac{1}{4}$ inch more than the greatest size of the coarse aggregate comprised in the concrete ;

whichever is the greatest dimension :

provided that the vertical distance between two horizontal main reinforcements, and the corresponding distance at right-angles to two inclined main reinforcements, shall be not less than $\frac{1}{2}$ inch, except where one of those reinforcements is transverse to the other.

(2) The provision of paragraph (1) of this by-law shall not apply at a splice, except for the distance between pairs of lapped bars.

(3) The pitch of main reinforcements in a reinforced concrete solid slab shall be not more than three times the effective depth of that slab.

(4) The pitch of distributing reinforcements in a reinforced concrete solid slab shall be not more than four times the effective depth of that slab.

7.12. ***Shear Reinforcement.***—Where the concrete alone is not sufficient to resist the shear in reinforced concrete without exceeding the maximum permissible shear stress specified in by-law 7.03, the whole of that shear shall be provided for by the tensile resistance of shear reinforcement acting in proper conjunction with the compressive resistance of the concrete :

provided that the magnitude of that shear shall not exceed four times the maximum permissible shear stress specified in by-law 7.03.

7.13. ***Stirrups.***—A stirrup in reinforced concrete shall pass round, or otherwise be adequately secured to the appropriate tensile reinforcement, and each end of that stirrup shall be properly anchored.

7.14. *Reinforcement in Solid Slabs.*—In a reinforced concrete solid slab spanning in one direction

(*a*) distributing reinforcements shall be provided at right-angles to the main tensile reinforcements of that slab ; and

(*b*) the area of reinforcement in each direction shall be not less than 0·1 per cent. of the gross cross-sectional area of the concrete at right-angles to the direction of the reinforcement.

7.15. *Compression Reinforcement.*—(1) Where compression reinforcement is required in a beam, it shall be effectively anchored by subsidiary reinforcement at points not farther apart, centre to centre, than twelve times the diameter of that compression reinforcement.

(2) The subsidiary reinforcement shall pass round, or be hooked over, both the compression and tensile reinforcements.

7.16. *Reinforced Concrete Walls.*—(1) So far as they relate to or affect reinforced concrete columns, the provisions of this Part of these by-laws shall apply to reinforced concrete walls, and for this purpose

(*a*) the expressions " effective height," " thickness " and " vertical " shall respectively be substituted for the expressions " effective column length," " least lateral dimension " and " longitudinal " wherever those expressions occur in this Part of these by-laws ;

(*b*) the expression " lateral reinforcement " in this by-law means reinforcement parallel to the length of the wall ;

(*c*) the provisions of by-law 7.09 relating to helical reinforcement shall not apply : provided that

(i) the aggregate cross-sectional area of the vertical reinforcements shall be not less than 0·4 per cent. of the gross cross-sectional area of the wall ;

(ii) the aggregate cross-sectional area of the lateral reinforcements shall be not less than 0·2 per cent. of the gross cross-sectional area of the wall ;

(iii) the diameter of a vertical reinforcement shall be not less than $\frac{3}{8}$ inch ; and

(iv) the distance between two vertical reinforcements and the distance between two lateral reinforcements shall not exceed 12 inches.

(2) Where in a reinforced concrete wall, the stresses do not exceed 75 per cent. of the maximum permissible stresses specified in by-law 7.03,

(*a*) the provisions of by-law 7.09 relating to transverse reinforcement shall not apply ;

(*b*) the aggregate cross-sectional areas of the vertical and lateral reinforcements shall respectively be not less than one-half of the aggregate cross-sectional areas specified in paragraph (1) of this by-law.

(3) Notwithstanding anything contained in Part V of these by-laws, the thickness of any external or load-bearing reinforced concrete wall shall be not less than 4 inches.

7.17. *Welding of Reinforcement.*—(1) Reinforcement shall not be connected by welding without the approval in writing of the Council :
provided that

(i) round or square reinforcements not exceeding 0·4 inch in diameter, and transverse to each other, forming a mesh-reinforcement in a solid slab may be connected (at the works where the mesh is fabricated) by electrically fusing the metal of those reinforcements at their point of contact ; and

(ii) that mesh shall, to the satisfaction of the district surveyor, be in all respects suitable, having regard to the particular circumstances of the case.

(2) The provisions of paragraph (1) of this by-law shall not apply to the connecting of stirrups and links to the main reinforcements of beams or to the connecting of transverse and helical reinforcements to the longitudinal reinforcements of columns.

7.18. Prestressed Concrete.—Notwithstanding the provisions of this Part of these by-laws, but subject to the approval of the Council in each particular case, prestressed concrete may be used in the construction of any building or part of a building.

CHAPTER 11

CAST STONE AND CONCRETE PRODUCTS

A LINE of development in concrete work in which considerable advance has been made in recent years is the casting of concrete to represent natural stone, and also the casting of articles such as cornices, kerbs, paving flagstones, pilasters, and figures, known as concrete products.

CAST STONE

There are two types of pre-cast concrete :

1. Cast stone or artificial stone. The material incorporates crushed stone of the type imitated and the appearance is similar to that of natural stone, but in many cases the strength and durability of the cast stone is superior to the natural material.

2. Pre-cast concrete products. This description refers to a normal cement-sand-gravel mix. There are many pre-cast products on the market, including floor slabs, wall blocks, steps, door canopies, door and window frames, sills, cornices, lintels, eaves units, prefabricated units for walls, floors, and roofs, stanchions, beams, rafters, purlins, kerbs, drain pipes, lamp standards, clothes-line posts, fencing units.

Both cast stone and pre-cast concrete products are produced in large quantities by specialist manufacturers. Special moulds and machines are used and the material is consolidated by vibration and carefully cured. These processes are scientifically controlled and the products are much superior to anything that can be produced by the builder who lacks the special machinery and experienced workmen.

The surfaces of good-quality cast stone and pre-cast products are regular, free from air-bubble holes and crazing, and the material is of uniform density throughout.

Pre-cast products are usually reinforced with mild-steel rods, mesh, or expanded metal. With products such as lintels this is obviously necessary so that working loads can be carried, but reinforcement is necessary also so that the products can be lifted without risk of fracture. For the latter purpose the products should be so reinforced that whichever way they are lifted the tensile stress is taken by reinforcement. Reinforcement also prevents shrinkage cracks in large units.

Pre-cast products are now often used in place of wood and natural stone. As concrete does not decay and can be given hard wearing properties the products are usually superior in durability to the older materials, and they do not require painting or preservative treatment.

The following information on pigments and proportions is quoted by permission of Concrete Publications, Ltd.:

Colour.—The following list gives the colours and shades produced by different oxides and pigments:

Buff and Yellow.—Yellow oxide or barium chromate.

Grey and Slate.—Manganese black or "cement black." (Ordinary lampblack is unsatisfactory.)

Brown.—Burnt umber or brown oxide of iron.

Blue.—Prussian blue or ultramarine blue.

Green.—Green oxide of chromium or greenish-blue ultramarine. Green also results from a mixture of yellow ochre and ultramarine blue.

Pink or Red.—Red oxide of iron, or crimson lake with alumina base.

Chocolate.—Manganese black, black oxide of iron or copper, and red oxide of iron, mixed together.

Black.—Manganese black or "cement black."

When matching colours it is advisable to mix a small batch, keeping a careful record of the quantities of materials and colour used, and make a trial slab so that the shade may be noted after the slab has dried out.

The colour and cement should first be thoroughly mixed in their

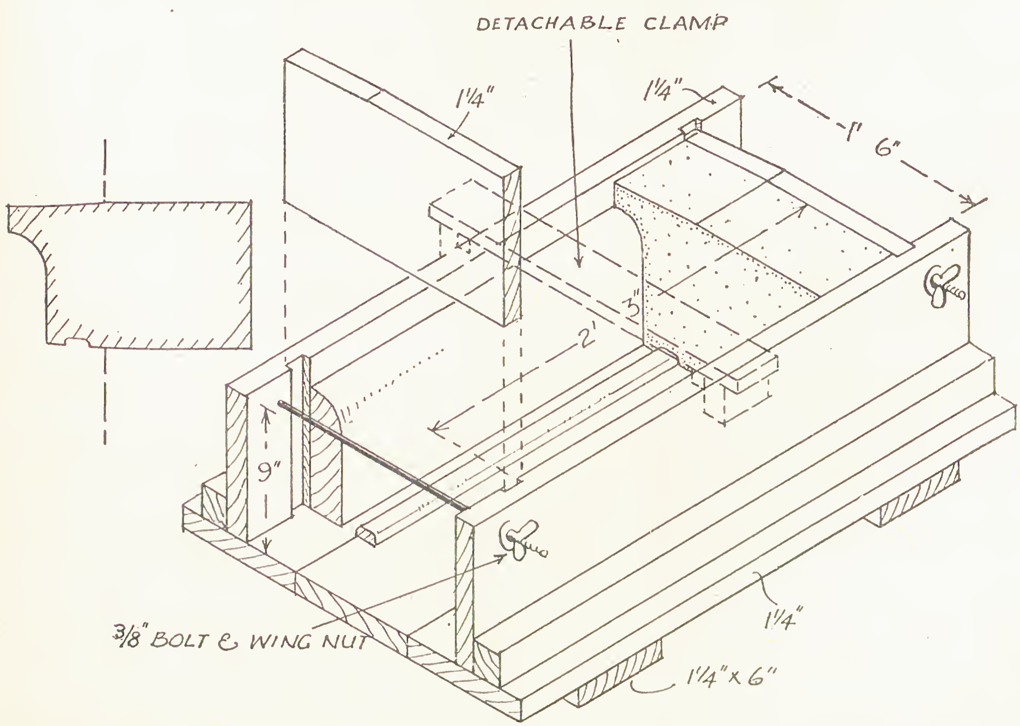


Fig. 194.—Wood hand mould for making pre-cast concrete cornice blocks.

dry state, and then the coloured cement mixed with the aggregate in the usual way. A period of mixing of at least two minutes is necessary, preferably longer. A better surface is obtained if a plastic mix is used, but due to the shape of the mould it is often necessary to use a fluid mix if all the detail of the mould is to be filled.

Matching Natural Stones.—Suitable proportions for matching various natural stones are given below :

Portland stone.— $1\frac{1}{2}$ parts crushed Portland stone $\frac{1}{4}$ inch to $\frac{1}{8}$ inch.
$1\frac{1}{2}$ parts crushed Portland stone $\frac{1}{8}$ inch down.
1 part white Portland cement.

Doulting stone.— 3 parts crushed Doulting stone $\frac{1}{3}$ inch down.
1 part of the following mixture :
80 per cent. white Portland cement.
20 per cent. grey Portland cement.
1 per cent. yellow oxide.

Ham Hill stone.— 3 parts Ham Hill stone $\frac{1}{4}$ inch to dust.
1 part Portland cement.
8 per cent. marigold pigment.

Runcorn stone.— 3 parts Runcorn stone $\frac{1}{8}$ inch down.
1 part white Portland cement.
2 per cent. yellow oxide.
1 per cent. red oxide of iron.

Crowborough stone.—3 parts crushed Crowborough stone through a 20×20 sieve.
1 part of the following mixture :
60 per cent. white Portland cement.
40 per cent. grey Portland cement.
4 per cent. yellow oxide.

White granite.— 3 parts china clay sand through $\frac{1}{4}$-inch sieve.
1 part of the following mixture :
50 per cent. white Portland cement.
50 per cent. grey Portland cement.
(Surface very lightly scrubbed with water when about 24 hours old.)

As natural stone varies in colour these proportions can only be tentative ; they will produce concrete the same colour as average stone.

Surface Treatment.—Colour may also be contributed to cast stone by the use of coloured aggregates, and to an extent by tooling, which latter, by breaking up the surface, imparts a tone to the material which may be regarded as a form of colouring. The operation is the same as that carried out by the stonemason, and with the same tools. Surfaces to be tooled will require to be of a finer aggregate than would otherwise be demanded, and a bush hammer may be used for removing the cement on the outside of the concrete and roughening the surface.

Where colour is required to be contributed to the concrete by the aggregate used, ordinary ballast concrete serves for the main walling,

Slab, 18 × 9 × 3 inches, with T and G ends (457 × 228 × 76 mm.).

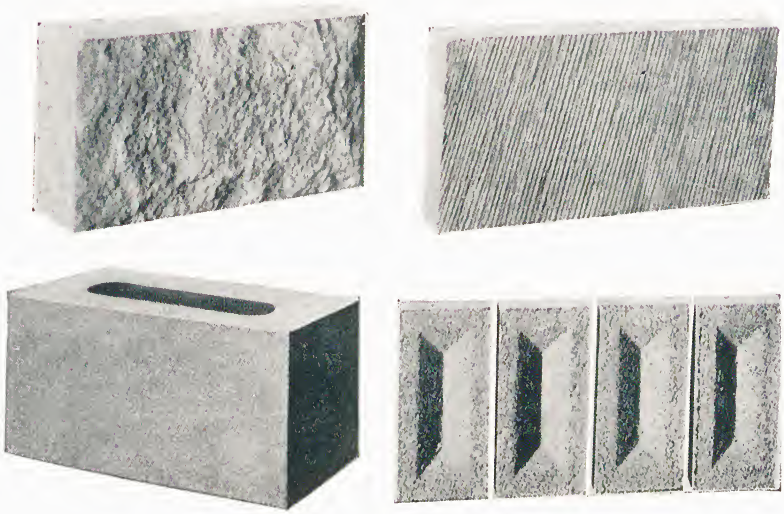


FIG. 195.—COMBINATION SLAB, BLOCK, AND BRICK MACHINE WITH FOUR TYPICAL PRODUCTS.

(Liner Concrete Machinery Co., Ltd.)

Fig. 196.—POLISHING RECONSTRUCTED STONE MOULDING (GIRLINGSTONE).

while a surfacing of fine stone or material furnishes the desired colour. The cement which comes to the surface must be cleaned off before the colour of the aggregate can be seen. A water spray may be used for this purpose on cast articles if applied immediately after the article is removed from the mould, but if the period which has elapsed is over six hours it will be necessary to scrub with a stiff brush. For the external surfaces of walls which can only be exposed after the cement has thoroughly set, the treatment is to scrub with a solution of commercial hydrochloric acid. The strength of this solution should be 1 part of acid to 3 parts of water. After the required degree of colour is given to the aggregate, the wall must be washed down with water to remove all acid.

Where the aggregate is not required to be tooled or rubbed down, there is not the same limitation as to size of aggregate, the only process being the washing of the cement which covers the aggregate, in the way already mentioned, when the inequalities of surface occasioned by the aggregate will enhance the effect occasioned by the texture. The following materials will provide colour in the resultant concrete, *viz.* white silica and white cement will produce white; black marble chippings may be used to give a black finish; white cement and yellow sand will give cream, and brown sand will give a buff finish; and varying finishes may be given by the use of broken pottery and coloured glass.

MATERIALS FOR CAST STONE

The materials used in the manufacture of cast stone, either for use on a building or as concrete products, are the same as those required for ordinary concrete, with the exception that, in accordance with the result required, the aggregate will require to be finer, more careful mixing is necessary, and greater attention given to, and time spent in, tamping and ramming.

Rapid-hardening Cement.—It will be readily understood that in such products as cast stone, which are formed in moulds, and to which it is desired to give attention to the surface as soon after the depositing as possible, the readiness with which the article may be freed from the mould is of first importance. Consequently, into the manufacture of such products the use of rapid-hardening cement enters even more than into the building of ordinary concrete.

In works where concrete products are produced on a large scale, the maximum output of each mould is of great economic importance, and provided there is sufficient room for curing and stacking, the more objects which can be made from the same mould in a given time the greater the output. Consequently, where a cement which takes twenty-four days to set can be replaced by one which takes twenty-four hours, the output will be very greatly increased.

Water.—The proportion of water in the making of concrete products is even more important than in making ordinary concrete. The real function of water is, as has been already said, to distribute the cement throughout the mix to every particle of sand as well as to those of the larger aggregate in order that they may become thoroughly coated with cement. The attainment of this result is of more importance in small articles which must be self-contained and stand alone, and of which many of the parts are slender, than in such solid matter as compose concrete walling.

The right quantity of water will give a mix that is neither too sloppy nor too dry. Too much water wastes the cement, as it causes it to run out of the mould, and too little water results in a mix that is not sufficiently strong to stand up to its work. The most economical concrete is formed with the correct amount of water rather than one having too much water and an excess of cement being supplied to overcome that excess.

Lintels should be suitably reinforced. Long sills, steps, etc., should be lightly reinforced so that they can be lifted without fear of fracture.

Mixing.—The mixing of the materials is of even greater importance for cast stone than for mass concrete. The measuring is carried out as already described, in barrows, or bottomless boxes, and where machines are employed by means of bins, and the turning over whilst dry should be most carefully supervised.

Tamping enters more into the production of cast stone and cast-stone products than into the production of mass concrete, as, moulds being used, it is essential that the mix should be thoroughly worked into all the turns and angles of the mould. Where a wet mix is used, this may be effected by stirring, and for a dry mix by tamping, and if necessary the concrete added a layer at a time, a thorough tamping being given between the deposit of each layer.

Where machinery is used for casting concrete products, a vibratory action is given to the mould, to aid the process of consolidation. In some machines considerable pressure is applied to the same end.

Surfacing—Glazing.—A glazed surface may be given to concrete products by spraying cement through an atomiser, or for such objects as floor tiles in concrete by the use of glass face plates in the mould.

A grained surface is also given in a similar manner by the use of plate-glass face plates to the moulds.

A combed or dragged face is given to products made face up by the use of any suitable combing tool.

Mosaic panels are formed in sinkings made by a projection on the face mould, afterwards filled in with different-coloured cements, laid in according to design.

Curing.—The curing of the concrete products may be carried out either in the open air or under cover or in special chambers by steam.

In the open air the curing will be satisfactory only when the atmospheric conditions are humid, and is best when a warm light rain is falling. When the weather is dry the products must be repeatedly

FIG. 197.—PRE-CAST PORCHES TO FRONT DOORS.
(G. A. Jellicoe, F.R.I.B.A., Architect.)

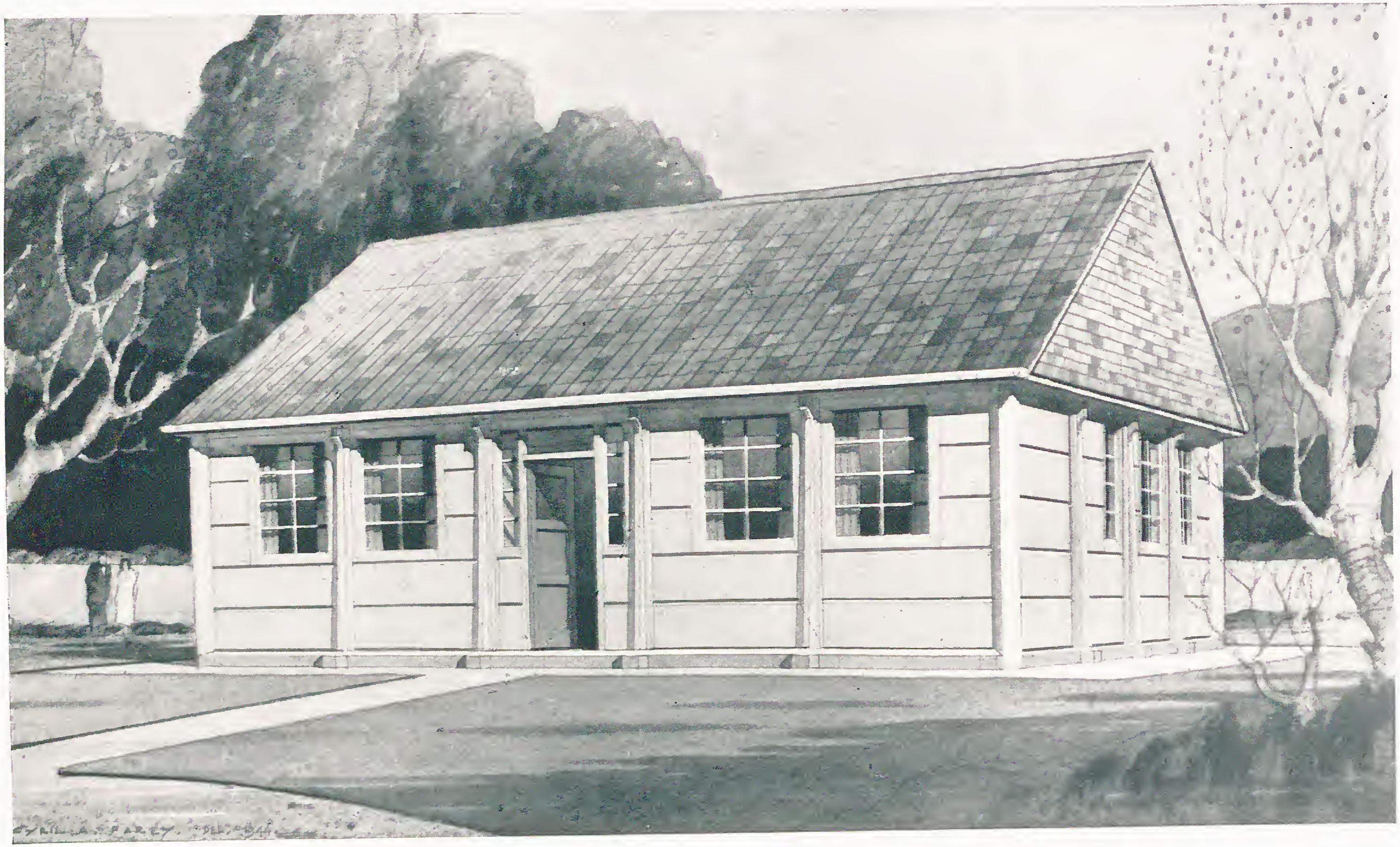


Fig. 198.—DESIGN FOR TEMPORARY HOUSE IN PRE-CAST CONCRETE.
(British Cast Concrete Federation.)

sprayed through a hose, and protected at all times from drying winds. The curing period lasts about three weeks.

Under cover the curing is carried out in sheds, the temperature of which is required to be maintained at 65° Fahr., and to contribute a moisture to the atmosphere water should be placed in the shed in containers suitable for evaporation over fire.

In works where greater output is required, curing may be carried out in twenty-four hours by means of steam. In such works several chambers are installed which permit of rotation of operation, three of the chambers being in use whilst the others are being emptied and filled again. The steam is admitted through water, the pipe itself generally running along a trough containing water, and after twenty-four hours in the steam chambers the concrete products may be stacked outside, though the best results are obtained by keeping them under cover and sprinkling for about a week before stacking in the open.

Stacking.—Concrete products are stacked in the open either in racks or on the ground. A layer of sand should be spread underneath them, and dependent upon the nature of the product itself, the stacking must be so contrived that air may pass freely around each article in the stack. To secure this in the most effective manner, the stacking upon open racks will be found the surest method.

CONCRETE ROOFING TILES

A line of development along which concrete may be very satisfactorily developed is in the construction of roofing tiles. There is a growing demand for these, especially since the discovery was made of incorporating with the materials composing them colouring in a satisfactory and durable manner.

Coloured concrete tiles are now made in many shades, obtained by varying the proportion of colouring medium, and they possess a texture and appearance so similar to that of a hand-made sand-faced clay tile that it is difficult to distinguish them from the best Broseleys.

The colour may be incorporated either in the cement used in making the tiles, or it may be painted on the surface after the tile is pressed and then sanded over.

Tiles are also made to represent Gloucester stone graded in sizes and coloured.

Manufacture.—For the ordinary roofing tile made of concrete, the aggregate is composed of 1 part of cement to 3 parts of sand, to which $\frac{1}{2}$–1 ounce of oxide to each tile, according to the colour required, is mixed in a patent mixer. The size of the tile is $10 \times 6\frac{1}{2}$ inches, and 525 go to the square. The mix is fed to a patent tile-making machine which is easily movable, being mounted on wheels ; and the best type of machine for this purpose is one which has a special indiarubber device fixed to all working parts to exclude the concrete.

Pressing.—The operation of the tile machine consists in placing a pallet in the mould which is then filled with mix and smoothed off. The head of the machine is pulled over close to the smooth surface; the pedal of the machine is then pressed with the foot, generating a pressure of $1\frac{1}{2}$ tons, and owing to the sliding motion of the head, suction is eliminated, thus permitting a wet mix which ensures the full strength of the concrete. The operation is of so simple a nature that a boy can turn out from 1,000 to 1,200 standard tiles per working day of eight hours.

Curing.—When made the tiles are placed in patent racks which stand at the side of the tile-making machine; when these racks are filled on both sides, they are lifted by a patent transveyor provided with pneumatic tyres to prevent all jarring such as might spoil the shape of the tile in transit. The rack is then wheeled to the curing chamber, where the tiles are subjected to steam treatment for twenty-four hours. After this the racks are again picked up by the transveyor and wheeled to a drying space, where they remain for fourteen days, stood on racks raised about 3 inches from the concrete floor.

Another form of lever transveyor is then inserted under the rack, and the tiles are wheeled to the lorry waiting to transport them to the job. From this it will be seen that tiles are not touched by hand at any time after their mixing.

Strength.—Particular attention has been given to the subject of rendering the tiles slightly porous in order that the effect of weathering upon the tile may be experienced to the full. A test of the absorption properties of the concrete tile afforded the result that after immersion in water for forty-eight hours the average absorption was 3·77 of water by weight. It was at first feared that such a tile would not withstand frost, but further experiment was made. After being soaked in water for forty-eight hours, the tiles were maintained at from 2° to 0° Fahr., *i.e.* 32° of frost, for twelve hours, and then allowed to revert to normal atmospheric temperature. There was then no sign of cracking or flaking.

As far as the strength of the concrete tile goes, a tile was supported at each end and loaded in the centre. This gave an average load carried before breaking of 76·4 pounds. Tiles have been found to resist before breaking a maximum load of 120 pounds.

The tests were carried out by the National Physical Laboratory.

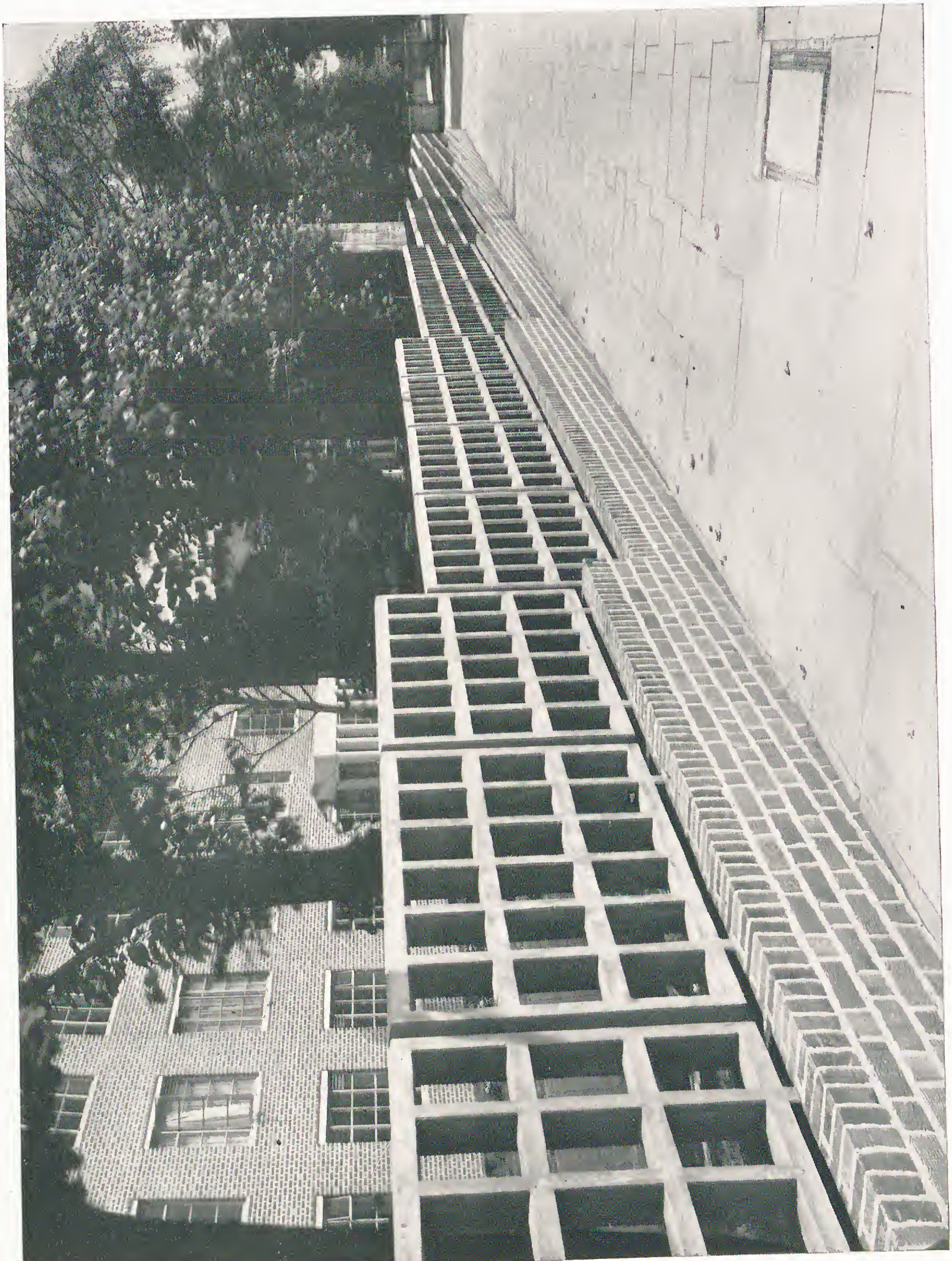


FIG. 199.—PRE-CAST CONCRETE FENCING.

CHAPTER 12

TILES AND TILING

BURNT clay tiles may be divided into three types :

1. Plain tiles of rectangular shape.
2. Pantiles, Spanish tiles, Italian tiles : these are traditional "single-lap" tiles.
3. Interlocking tiles : these are modern "single-lap" tiles with interlocking edges to ensure weather-tightness.

PLAIN TILING

Standard hand-made and machine-made plain clay tiles, as described in British Standard Specification No. 402, are $10\frac{1}{2} \times 6\frac{1}{2}$ inches with a plus variation not exceeding $\frac{1}{8}$ inch on the width and $\frac{1}{4}$ inch on the length. Hand-made tiles have a minimum thickness of $\frac{1}{2}$ inch, and machine-made tiles $\frac{3}{8}$ inch.

Hand-made plain tiles 10×6 inches and 11×7 inches are also made.

A plain tile has two nibs (or a continuous projection) for hanging to battens, though the older type of nibless tile is still made to special order. A tile should be slightly cambered in its length, but it is desirable that the cross section should be straight to avoid rain being blown up the laps.

Eaves and Verges.—Eaves and top courses must be "short" and $8 \times 6\frac{1}{2}$-inch tiles are used for these courses, requiring $5\frac{1}{2}$ tiles per yard run.

Tile-and-a-half tiles are used at verges and gables in alternate courses in order to give a straight verge. On an average about 40 tile-and-a-half tiles are required to 1,000 standard tiles.

General Fittings.—The following "general fittings" are made for use with plain tiling :

Vertical square-angle tile, left and right hand. Vertical octagonal tile, left and right hand. Hip tiles to lay in courses : angular, semi-bonnet, bonnet. Octagonal bay-window hip tiles. Valley tiles : angular and rounded. Hog-back ridge tiles 12 inches long in various pitches. Half-round plain ridge tile 12 inches long in various pitches. Half-round capping ridge tile (socket and spigot) 12 inches long in various pitches. Plain angular ridge tile 18 inches long in various pitches. Capped (socket and spigot) angular tile 18 inches long in various pitches.

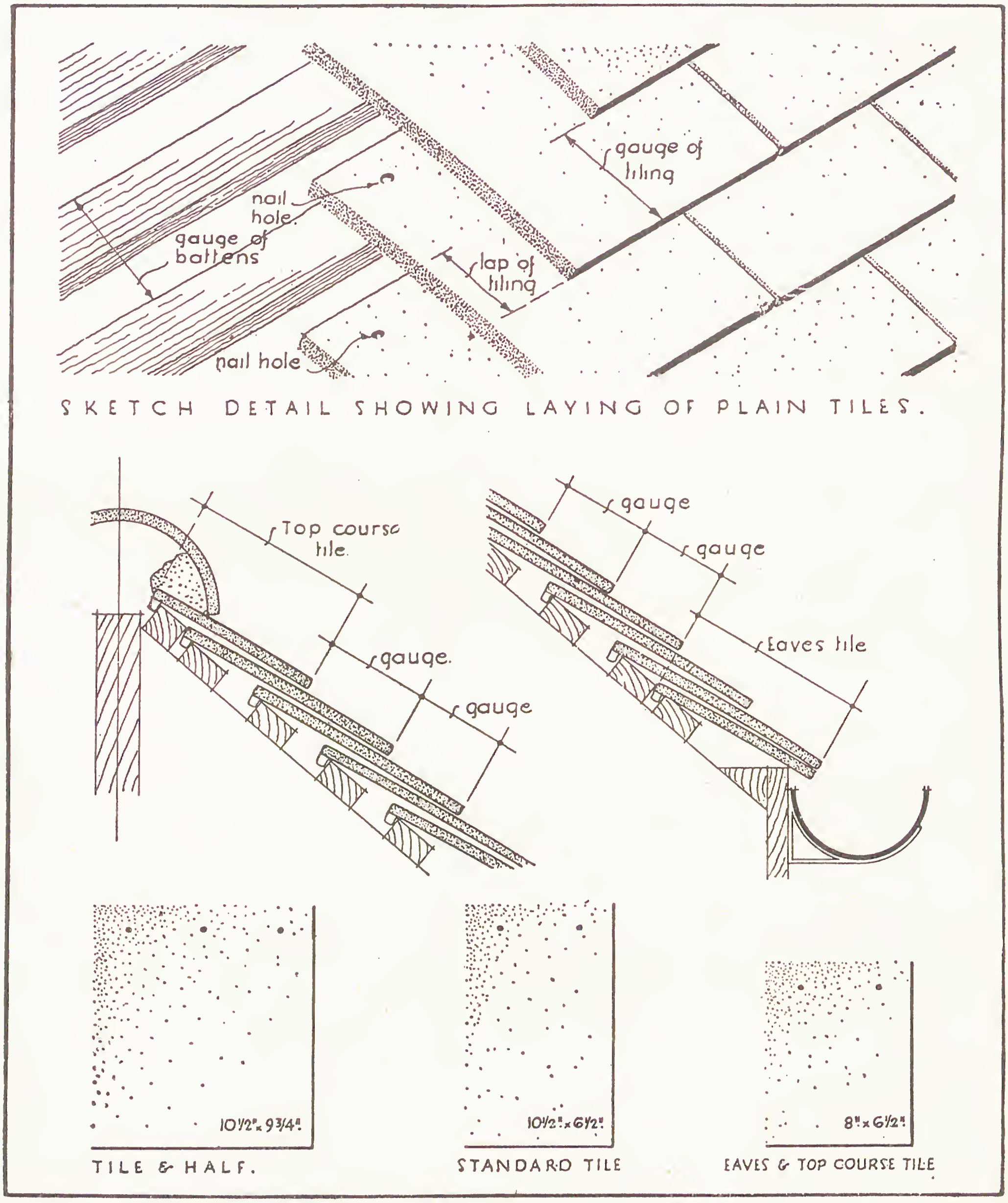


Fig. 200.—Plain tiling—illustrating gauge and lap. (*Courtesy of Wheatley & Co., Ltd.*)

Sub-roofing.—This is the treatment of the roof between the rafters and the tiles. There are five methods in common use :

1. Open battens on rafters.
2. Open battens with mortar torching at heads of tiles (underside).
3. Battens with underfelt or building paper laid over rafter.
4. Battens, underfelt, and boarding.
5. Battens, counter-battens, underfelt, and boarding.

Regarding the above methods: tiling on open battens may admit rain and dust in strong winds.

Mortar torching prevents such direct infiltration but, though an old method, it is not recommended as it provides a capillary means of conducting moisture to roof timbers and prevents ventilation under the tiles. It is better to lay underfelt (often called sarking felt) or building paper over the rafters, projecting such fabric over the eaves for drainage.

The best method is No. 5; covering the boarding with sarking felt and then laying the horizontal battens on counter-battens running up the roof from eaves to ridge. This enables any water penetrating the tiling to run down the roof (between the counter-battens), and makes the roof dust and draught proof, allows the tiles and battens to be ventilated, and gives good thermal insulation.

An overhang of 2 inches is given to verge tiles, and they should be pointed in cement. A plain tile "undercloak" should be bedded in

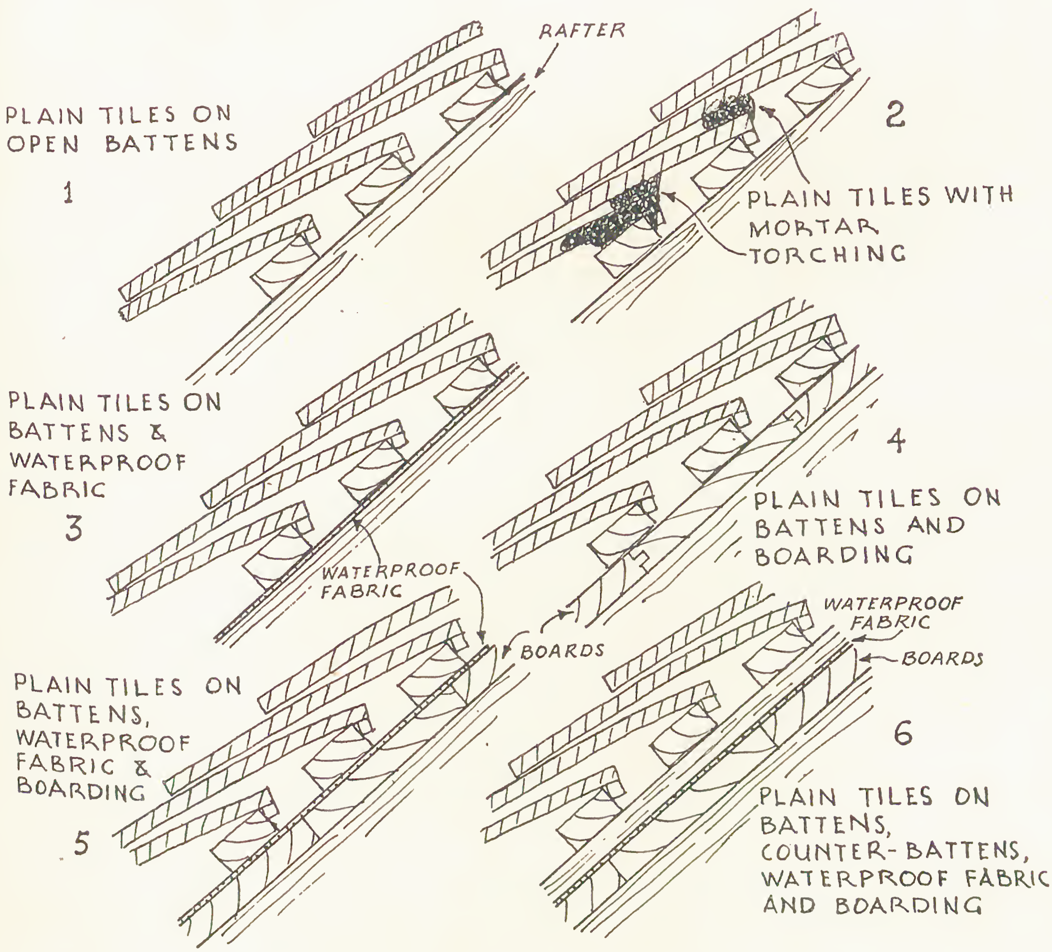


Fig. 201.—Various methods of sub-roofing to plain-tiled roofs.

mortar along the gable. This provides a neat finish to the verge, the space between tiling and undercloak being filled with mortar.

An Under-eaves Tile, also used in the top course under the ridge when it is known as an "under-ridge tile," is used to avoid cutting, and is made of the following sizes: 7 inches to 8 inches in length by 6½ inches wide by ½ inch thick. This reduced length is found necessary in order to maintain the same exposed surface in the bottom or first-laid course of tiles. This exposed surface is termed "the gauge." The eaves course is laid double, and should rest on a tilting fillet.

Hip and Ridge Tiles are made in inverted V shapes, 18 inches long by ½ inch thick, and in half-round section of 9 inches diameter by 18 inches to 24 inches long by 1½ inches thick.

The inverted V type is also supplied with a cresting shaped to patterns, but the use of this decorative tile is fortunately dying out.

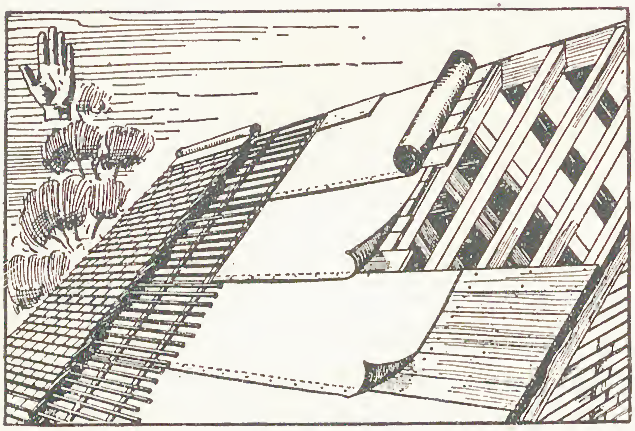


Fig. 202.—Tiled roof with counter-battens, battens, underfelt, and boarding. (*Courtesy of D. Anderson & Son, Ltd.*)

Hip and ridge tiles are either bedded solid in hair mortar and pointed in cement, or alternatively, have the bottom edges bedded in mortar with an air space left around the wood ridge. This latter is the better method, as it provides ventilation for the ridge board and upper ends of the roof timbers, and so prevents damp collecting, and its natural result, dry rot, in that portion of a roof.

Further Varieties.—Further varieties of tiles used in roofing include:

The Waterib Tile is manufactured by the Coal Brookdale Co., Ltd., and has a cross rib near its top edge on the upper or face surface as an additional preventive against driven rain or snow. The over-all dimensions of this tile are the same as those of the ordinary plain tile, *viz.* 10½ inches long by 6½ inches wide.

Rustic and Multi-coloured Tiles.—Of recent years a definite movement to break away from the too decided uniformity of colouring, outline, and texture in roof tiling has been evident; and to meet this, tiles of a variety of colouring and a greater irregularity and variation in sizes are now supplied. The colours, which shade from bright red, through crimson lake, and purple to chocolate, when mixed with care, give to the roof a varied colour effect with pleasing results.

Pantiles are tiles made from red-burning porous clays, in section a flat S on its side. Ordinary pantiles should be laid on underfelting to prevent water penetrating.

The size of the pantile is usually $13\frac{1}{2} \times 9\frac{1}{2} \times \frac{1}{2}$ inch, and the weight of a tile $5\frac{1}{4}$ pounds. They are laid to a 10-inch margin, 180 being required per square, and they weigh per square $8\frac{1}{2}$ cwts.

The top right-hand corner of each pantile is cut off diagonally to assist in laying and to allow overlap, otherwise there would be a double thickness at this point, resulting in a gaping joint.

In certain buildings such as farm buildings, bakeries, foundries, and sheds, a certain amount of ventilation through the roof covering is an advantage, and to ensure this the pantile is serviceable if laid dry with an overlap of 4 inches.

Interlocking Tiles.—For domestic buildings a modern development of the pantile known as the *Interlocking* type is supplied.

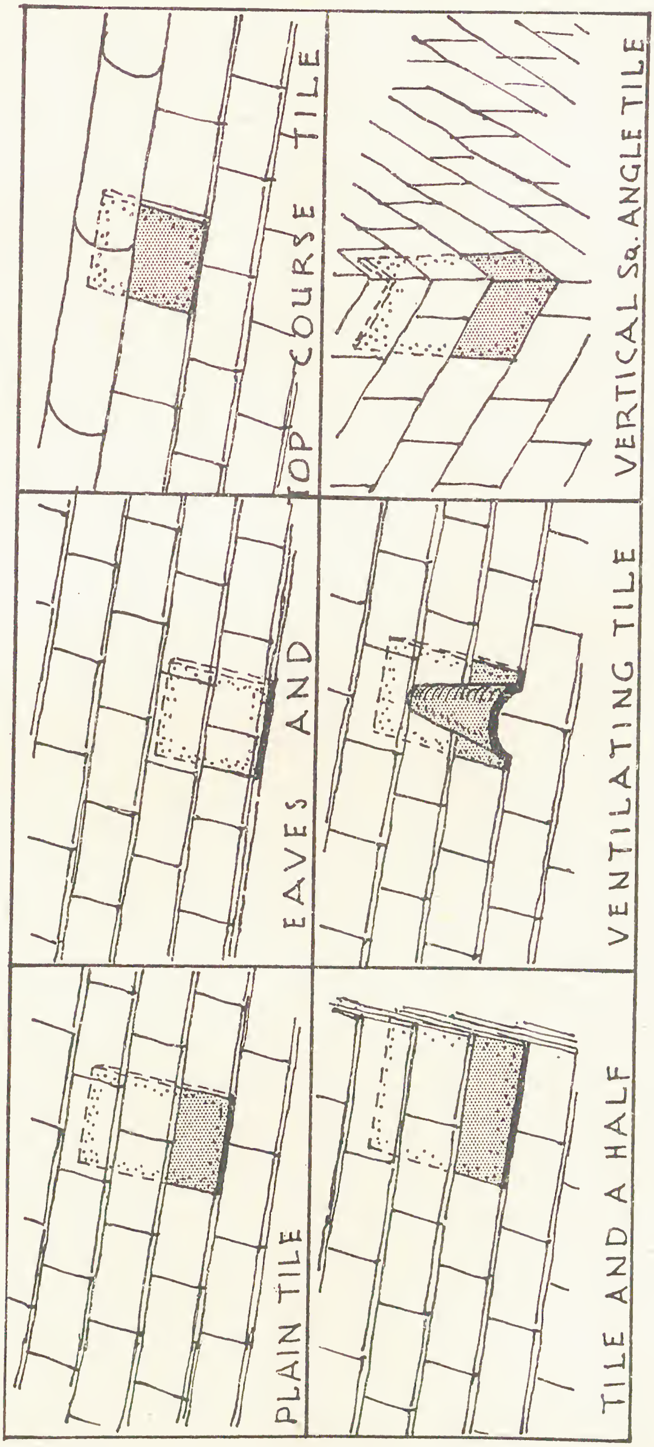


Fig. 203.—Tile "fittings" for use with plain tiles.

The *Bridgewater or Somerset* interlocking tile is the best known British example of this type of tile. These average from 14 inches to 16 inches long by from 6 inches to 9 inches wide, and are laid from 10 inches to 13 inches gauge.

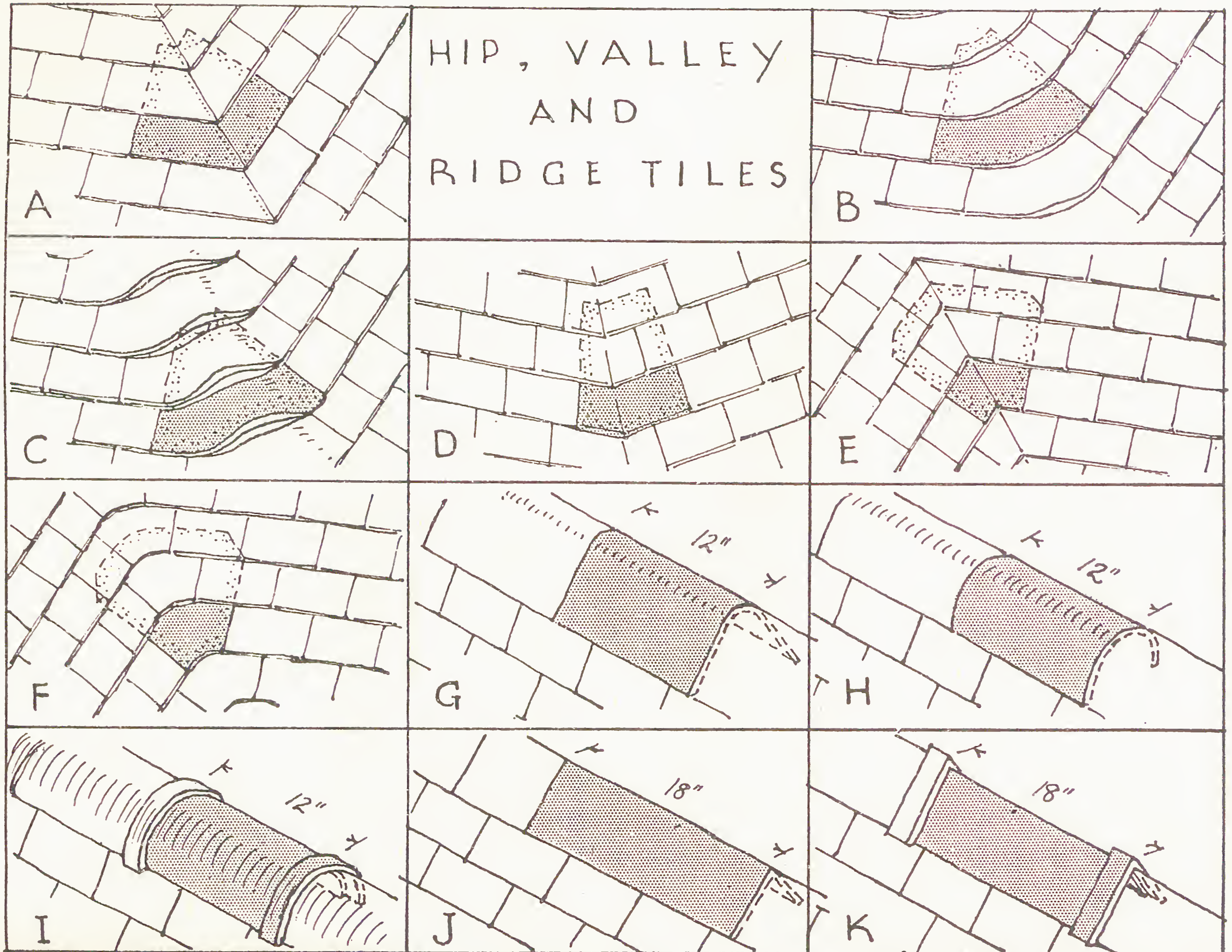


Fig. 204.

Interlocking tiles are also imported from France, and are known as the *Marseilles Tile* and the *Courtrai-du-Nord Tile.* The Marseilles tile is $16\frac{1}{2} \times 9\frac{1}{2} \times \frac{1}{2}$ inch, and is laid to a $13\frac{1}{2}$-inch gauge, 125 tiles being required per square, and weigh $6\frac{1}{2}$ cwts. per square.

Italian Tiles consist of two parts, one a trough-shaped tile, having the trough wider at the top than the bottom, and the other a half round, wider at the bottom than the top, which fits down over the upturned edges of the troughs. The troughs are laid on the roofs with their edges upwards, and the half-rounds are then laid over the adjacent upturned edges.

Asbestos-Cement Pantiles.—These are the same shape as ordinary pantiles. The colour is russet-brown and the depth of tone varies from tile to tile so that the appearance is not monotonously uniform. The material is durable and weatherproof.

There are two sizes: large pantile, $15\frac{3}{4} \times 13\frac{1}{4}$ inches. Small pantile, $15\frac{3}{4} \times 9\frac{7}{16}$ inches. The standard lap is 4 inches, and the battens are spaced at $11\frac{3}{4}$-inch centres.

The tiles are of regular shape and are notched to enable them to fit closely. In a sheltered position the tiles can be laid on open battens if the pitch is at least 40 degrees, but for an exposed position or low pitches underfelt should be used.

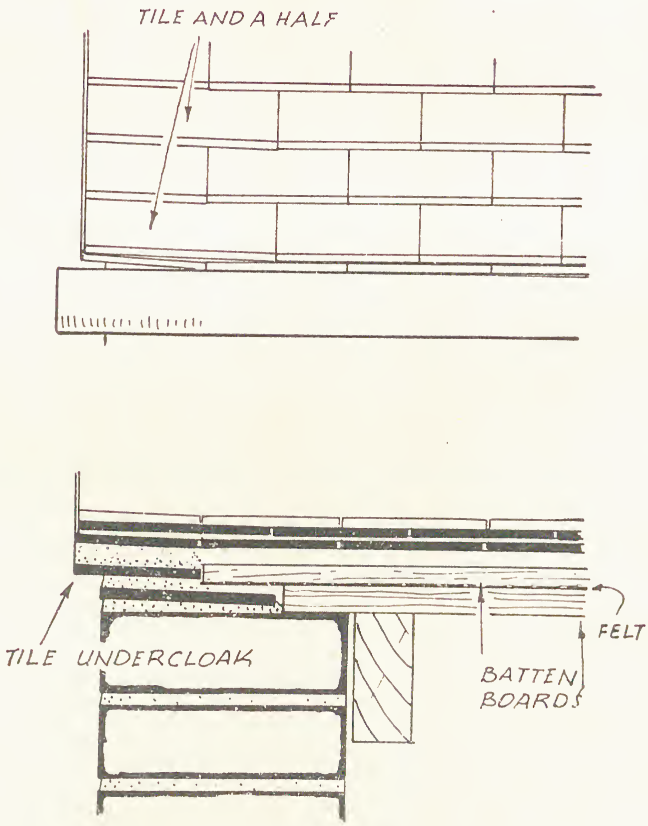


Fig. 205.—Verge in plain tiling with tile undercloak.

Special eaves tiles with stopped ends, and other specials, are made, and a concrete-lined asbestos-cement half-round ridge tile can be used on ridges and hips.

Originally made only in cement colour, they were open to the objection that they formed an uninteresting-looking roof. This objection no longer obtains, since methods have been discovered of imparting almost any desired colouring to the cement used in their manufacture, red, blue, grey, russet, and intermediate shades being now obtainable.

Asbestos Sheets belong more appropriately to the subject of " *Slating.*"

Concrete Tiles.—Tiles made of concrete to resemble clay plain tiles and also Cotswold-stone tiles have been described in Chapter 11 of this volume.

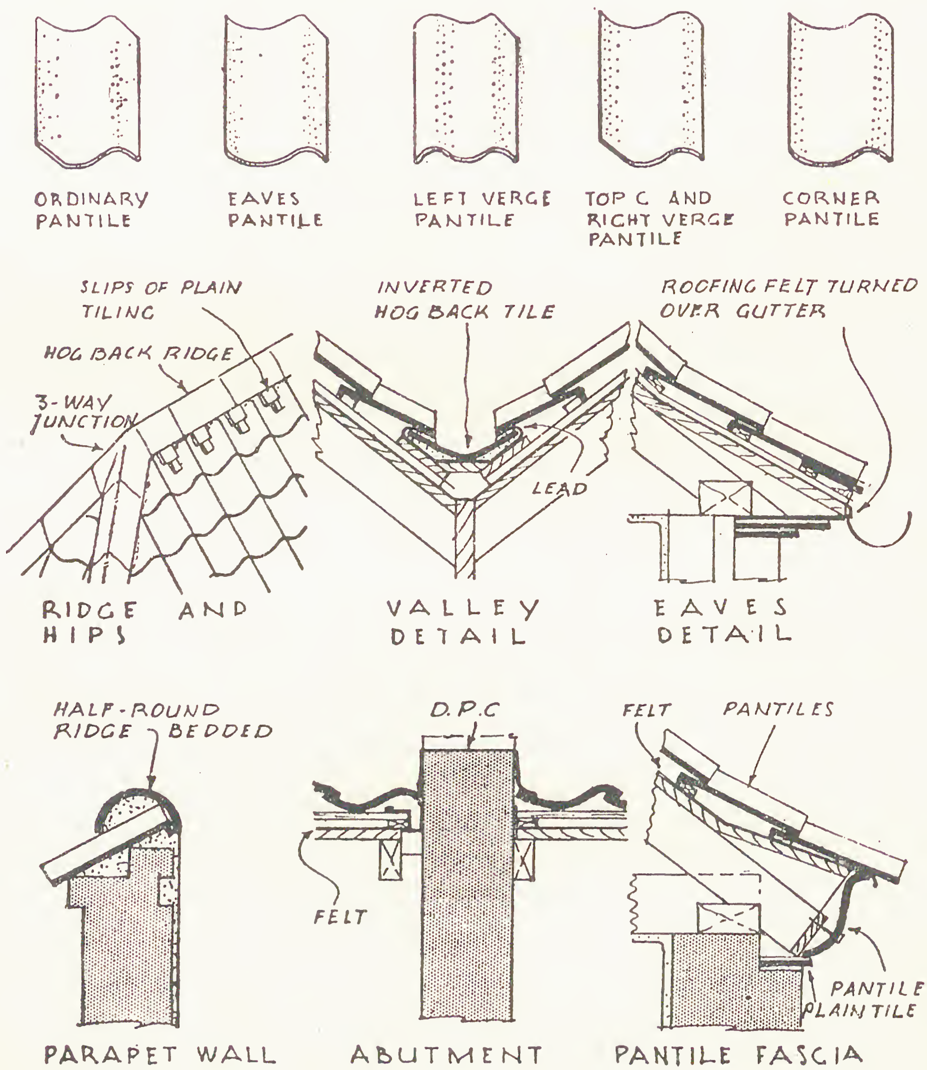


Fig. 206.—Pantile details. (*Courtesy of Wheatley & Co., Ltd*

Tile Hanging on Walls.—Walls are covered vertically with tiles hung to battens, as are also the vertical faces of dormer windows, the method being known as *Weather Tiling*.

Ordinary plain tiles are used in tile hanging on either brick walling having the bricks built on edge, or ordinary brick walling battened, or on framework battened. The tiles are nailed to the battens with a lap of

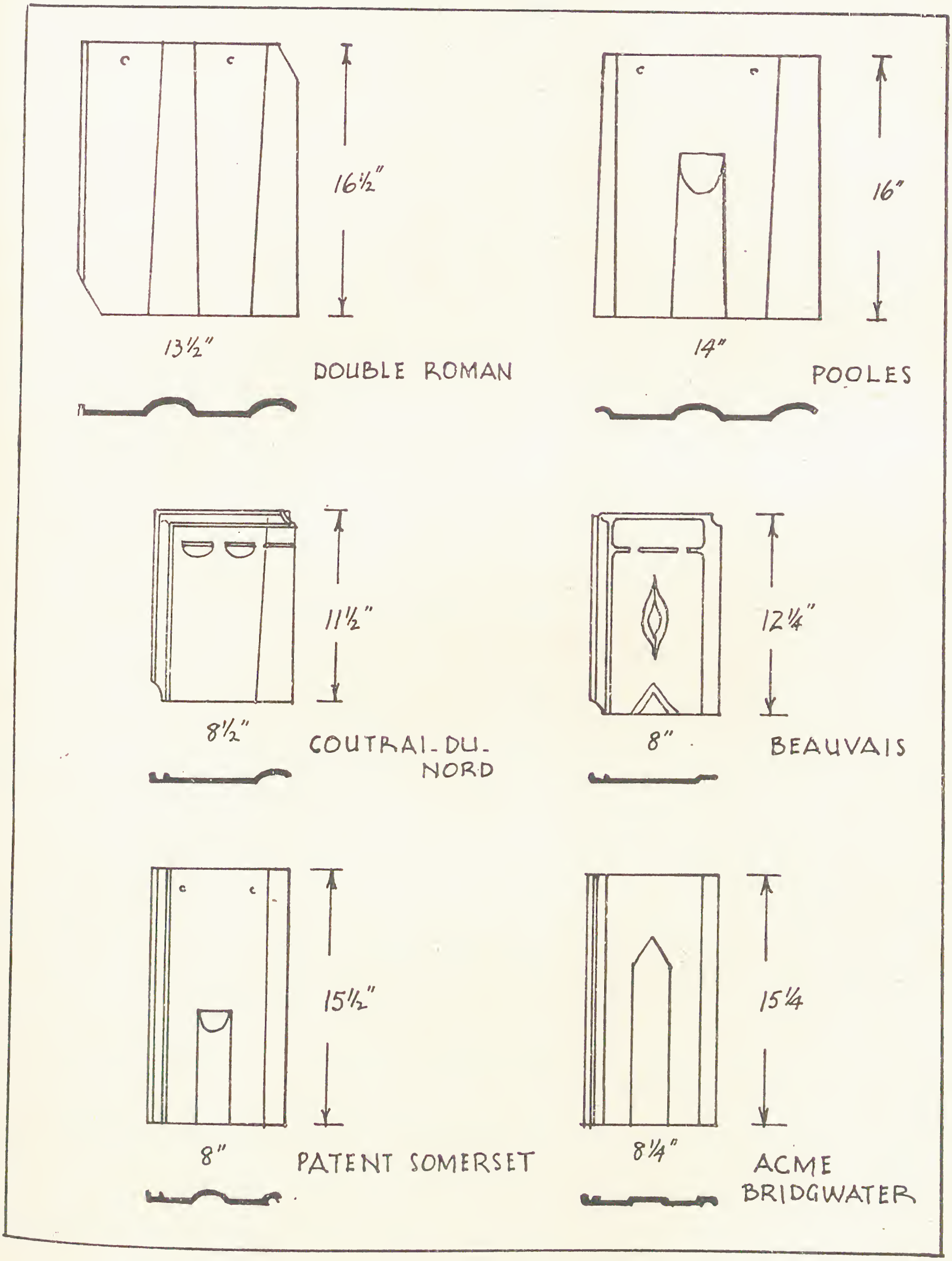


Fig. 207.—Examples of single-lap clay tiles.

from $1\frac{1}{2}$ inches. The battens are $1\frac{1}{2}$ inches wide $\times$ $\frac{3}{4}$ inch thick, and nailed to bed joints when over brickwork, where possible. To find the gauge or distance at which the battens must be nailed, deduct the lap from the length of the tile and divide the remainder by 2. The gauge lines are then snapped on with the bricklayer's chalk line and the tops of the battens nailed to line. Special-made angle tiles are provided for the corners, having one side $7\frac{1}{2}$ inches wide and the other 5 inches wide alternately.

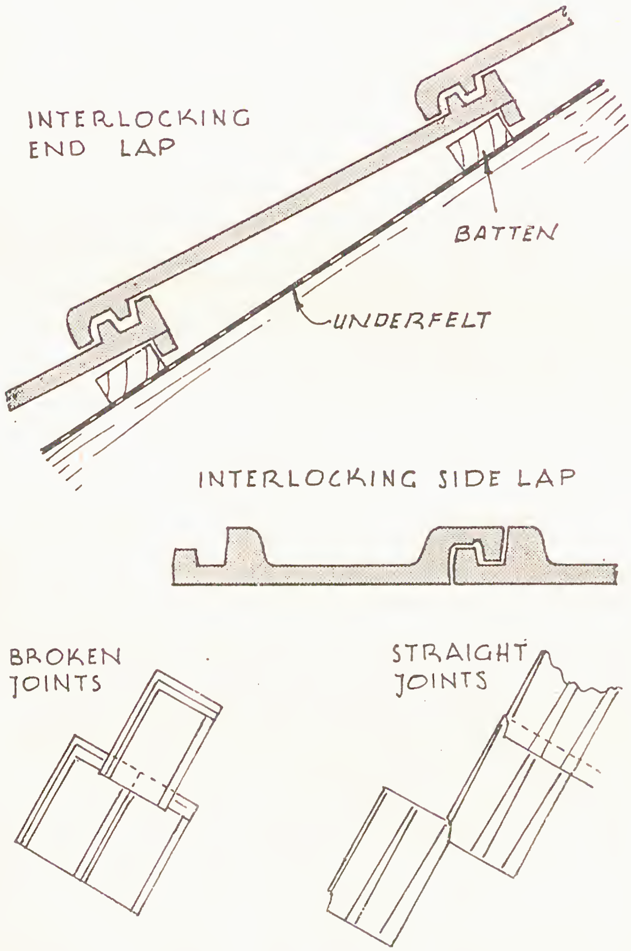


Fig. 208.—Typical single-lap tile with interlocking joints.

Weather tiling should be given a projection over all door and window openings, and is often so treated to mark the floor line of the upper storey. Where the tiling is over brickwork, a projecting course of splayed headers on edge is formed to project about 3 inches, and over the splay of this a course of tiles reversed is laid in under the first course of ordinary tile hanging.

The reveals of windows present some difficulty in finishing, and a good method, where the walling is in brick, is to build out the jamb 3 inches from the face of the brickwork so as to form a projection against which the tile hanging may be stopped. The tiling over this projection at the head of the window opening may be finished as already described for the oversailing course at the first-floor level.

Where the windows are set back in the opening, the sides of the tile hanging may be pointed in cement and have lead aprons at the sill turned up into a throating in the underside of the sill. If this throating be made wide enough, a course of tiles may be hung over the lead apron to conceal it from view. This course must be bedded in cement.

Tile Hanging to Dormer Windows may be finished either against a wood fascia nailed to the window frame or the tile hanging to the cheek may be carried round on the fascia with special-made angle tiles.

Clays used in Tile Making.—The clays used in making tiles should consist of silica and alumina, partly free and partly in combination. It is

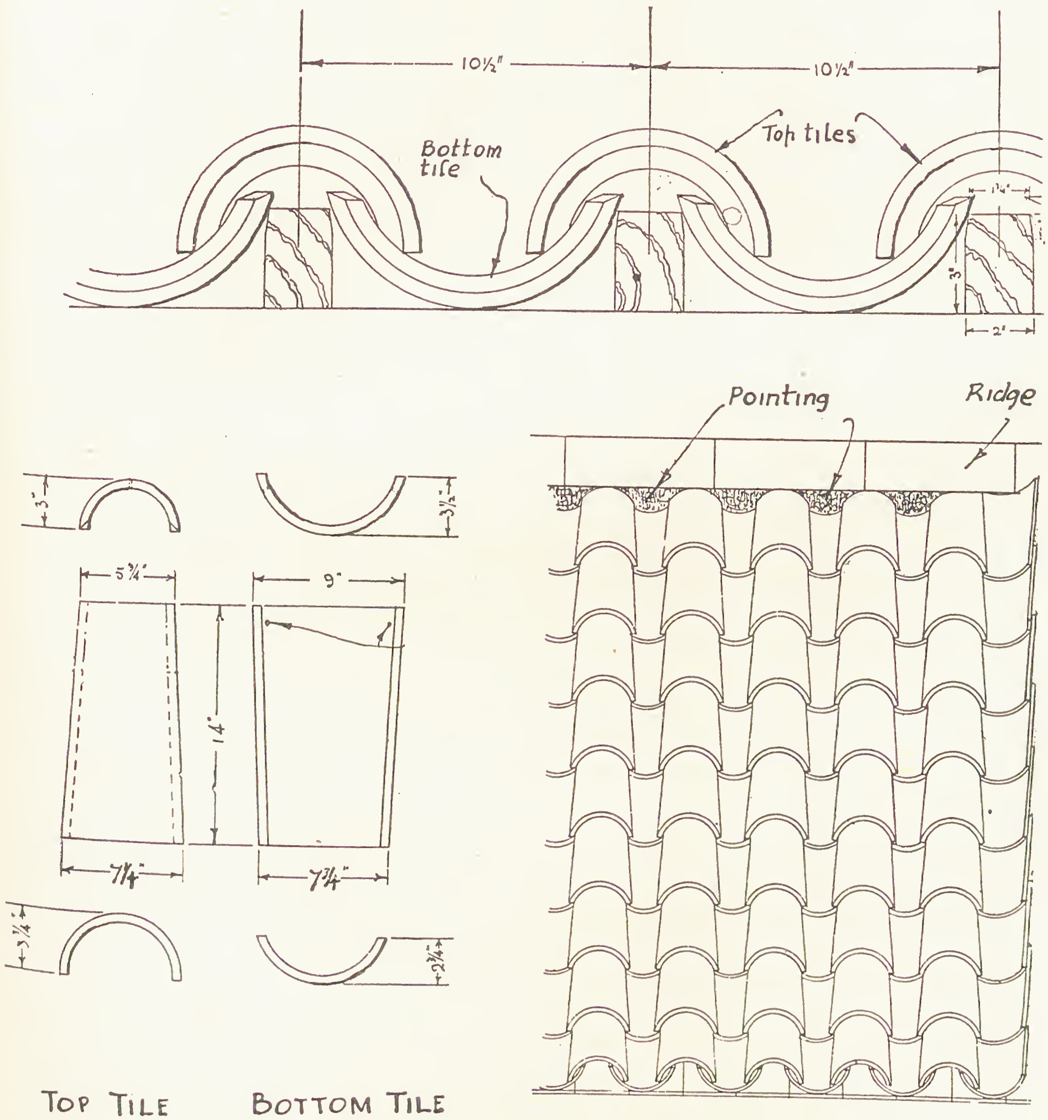


Fig. 209.—Spanish tiles. *(Courtesy of Wheatley & Co., Ltd.)*

likely that there will also be certain impurities present in most of the clays used. These consist of oxides of iron and magnesium up to 10 per cent.; chalk up to even 40 per cent. in some clays; and organic matter up to 15 per cent.

Alumina (Al_2O_3) is almost wholly combined with the silica as silicate of alumina.

Silica (SiO_2) is sand or flint, and up to 15 per cent. assists in the internal burning of the clay.

The Oxides act partly as fluxes in the burning and affect the colouring of the finished article. When only a normal amount is present, the final colour will be from pink to red, but excess of oxides turns the finished product blue.

The Organic Matter is present in vegetable form, and up to 15 per cent. it assists in the internal burning of the clay.

Manufacture of Clay Tiles.—*The Process of Manufacture*, so far as the preparation and the burning of the clay, is the same for tiles as for bricks. The clay is first washed and sieved until it runs out as a fine malm, which consists of a mixture of the required ingredients necessary to form a clay of fairly exact proportions, and ground together with water in a wash mill. It is thus reduced to a fine " slurry," when it is further screened and run into " settling backs." The water is then drained off, and ground tile, known as " grog," is added and grit to reduce the shrinkage.

Pressing the clay into tiles is carried out both by hand and by machinery.

The Hand-made Tile is " thwacked " into a mould of the required size and moulded into the required shape.

The process of moulding is carried out in either of two ways :

The Sand-moulded Tile is formed in a mould of slightly larger dimensions than the required size of the finished tile. The inside of the mould is first sprinkled with a layer of sand before the clay is moulded into it, and another layer of sand is then spread over the moulded clay. The sanded clay is turned out of the mould on the pallet and taken to the hack.

The Stop-mould is the exact size of the tile, and into this the clot of clay is thwacked and moulded to shape. It is then taken away in the mould to covered drying racks, where it is left at least forty-eight hours.

Machine-made Tiles are pressed out of a machine in strips of the required thickness and wire-cut to the required length. The cut lengths are then stacked for a few days, when they are put into a press, the mould of which is so shaped as to form the nibs. The longitudinal camber is given by working the tile by hand over a leather horse and the nail holes are also formed by hand. Holes for wood pegs require to be larger than holes for nails.

The Hand-made Tile has certain advantages over the machine-made tile. It is thicker, heavier, and has a superior appearance when laid, in that it is not so regular and has a texture which soon weathers to varied tones of colour.

The Machine-made Tile is preferred by those who require a more precise neatness and a uniformity of colour. Neither will the colour alter much with time, as this tile is formed with hard outer skin of a semi-glazed nature.

The Properties of a Good Tile are that it should be free from twist, cracks, and warp. It should also be tough and ring clearly when struck. When buying tiles, it is advisable to break one or two across to discover the texture internally. This should be even and homogeneous in section, and there should be no stones in the interior. A tile should not be unduly porous, or it will be readily broken in frosty weather.

Gauge and Lap.—Whereas these terms are sometimes confused, they have distinctive applications—the *Gauge* being that surface which is exposed to the weather ; whilst the *Lap* is the distance that the bottom of the tile extends over the head of the second tile below it ; *i.e.* in other words, it is the width at that part of the roof covering where there are three thicknesses of tiles.

The lap for tiling on average slopes is $2\frac{1}{2}$ inches and the gauge 4 inches for pitches of from 36° to 45°.

The gauge may be calculated from the following formula :

$$\text{Gauge} = \frac{\text{length of tile} - \text{lap}}{2}$$

and as the lap is specified in the directions for laying, as, for example, as follows, the tilting to be of . . . laid to a $2\frac{1}{2}$-inch lap, the formula resolves into :

$$\frac{10\frac{1}{2} - 2\frac{1}{2}}{2} = \frac{8}{2} = 4 \text{ inches.}$$

It is sometimes preferred to specify the gauge, but given either the lap or the gauge, the other can be calculated very readily. The advantage in specifying the gauge is that this immediately gives the distance apart at which the battens are to be fixed, as they are the same.

Tiles are a more expensive roof covering than slates as they require stronger roof timbers. Also tiles form the best roof covering when the pitch is steep, which requires more feet run of timber.

However, their appearance is generally considered as sufficient compensation for the additional cost, and this latter may be reduced by omitting the nailing and just hanging the majority of the courses by the nibs over the batten nailing, say, every sixth course only. Thus in comparing actual cost, the time taken in holing and nailing slates must be taken into account.

Hips.—Hips are formed either with tiles cut to mitre with the plain tiling and having lead soakers interleaved, or with the following special-made tiles : (*a*) purpose made ; (*b*) bonnet-hip tile ; (*c*) half-roun ridge ; (*d*) cone-hip tiles.

The first method necessitates a considerable amount of labour in cutting and in the insertion of the lead soakers. The effect of the finished work, though neat, is rather thin looking, but the result, if the 5-pound lead soakers are properly interleaved, is a sound watertight job. It cannot, however, be recommended as economical.

An alternative, saving labour, is to substitute for the interleaved lead soakers a narrow strip of lead turned over the hip and down both sides of it.

Hip Tiles must be nailed and bedded to prevent slipping; whereas, valley tiles, by reason of their shape, cannot slip in the same manner, and do not require the same fixing.

In measuring the lineal foot run of laths required for tiling laid with a 4-inch gauge per square, the following calculation is necessary. The width of a square is 10 feet, and with a gauge of 4 inches there will be 3 lengths of lath to the foot = 30 lengths in 10 feet and 10 feet long = 300 feet run per square.

The *Purpose-made Tile* for hips is open to the same objection as regards flat appearance, but does not necessitate the same amount of cutting, as the wings are formed at the required angle to fit the sides of the plain tiling. The purpose-made tile is formed for use in alternate courses, having one wing long and the other short, right and left alternately, to bond with the vertical jointing of the tiles. In length they are the same as the plain tile used. The internal angle of this hip tile must be at the required angle to allow it to fit down lightly on to the hip rafter and also on to the hip sprocket. It is secured to the hip timber by a single nail driven through a hole near the top of the angle. It is sometimes difficult to get these tiles in exactly the same colour and texture as the plain tiling, which is thought to be undesirable, though why a hip tile should be exactly the same colour and texture as the plain tiling is not evident. No doubt this is a matter of taste; but it is a fact that any method of outlining the hips often improves the appearance of a roof in a very marked degree, and as the result is achieved by this without additional cost, it is, from that aspect, to be recommended.

The *Bonnet-hip Tile*, also termed the "Granny," is an old-time curved slab tile, so named from its imagined resemblance to a granny's sun-bonnet. This has the advantage of the former in not necessitating cutting of the plain tiling, and by its upward curve to the line of each course at the hip it adds a feeling of strength to the hip, missing in the use of either of the former hip tiles.

This upward curve is contributed by the shaping of the bottom edge of the bonnet-hip tile, which is sometimes formed in a double "ogee," or it may be formed by increasing the thickness of the bedding mortar.

This hip tile is nailed at its top end to the hip, where the curve is flattened out to give a satisfactory fit.

The bottom course of a hip formed with the bonnet-hip tile will often present some difficulty, as it does not look quite satisfactory if the rounded shape of the tile is allowed to show. A tile tongue 2 inches wide is inserted to overcome this difficulty.

Fig. 210.—SWEPT VALLEY IN PLAIN TILES—NO LEAD USED IN THIS VALLEY.

(Courtesy of George Legge & Sons, Ltd.)

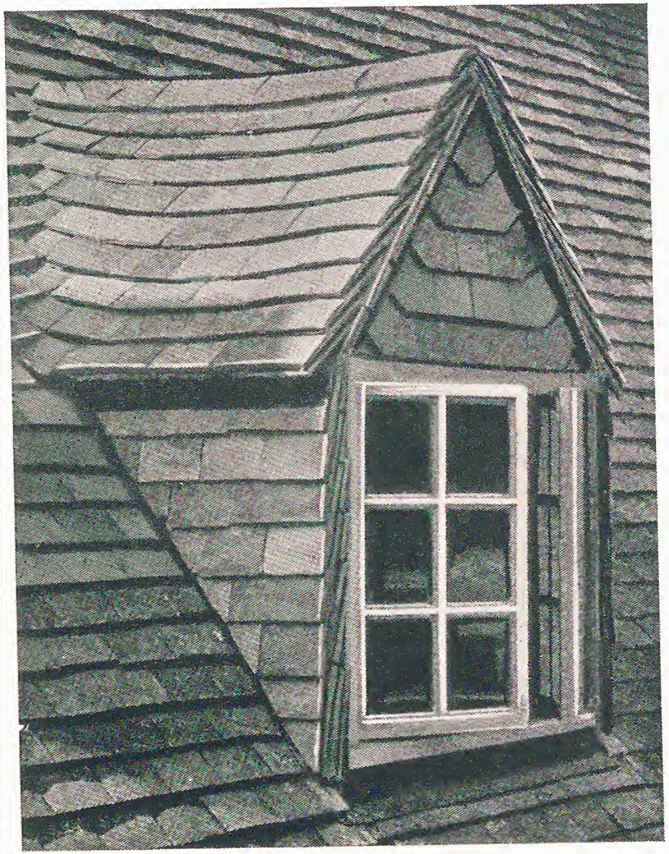


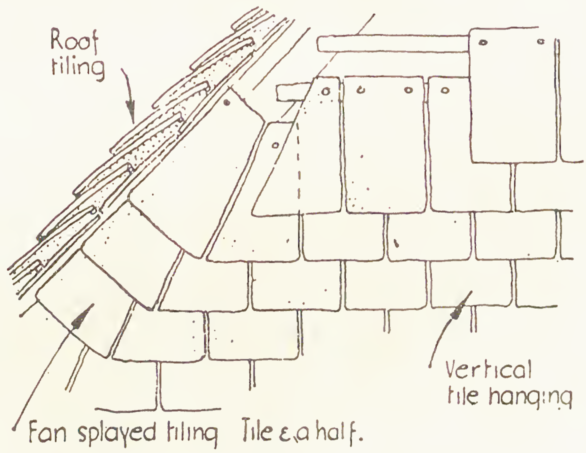
Fig. 211.—DORMER WINDOW WITH LACED VALLEY TILE-HUNG CHEEKS, AND TILE-HUNG GABLE.

Cone Hips are lapped one over another and bedded down on to the ends of the plain tiling courses. Though this method, if properly bedded, makes a sound job constructionally, it does not afford a very pleasing appearance, in that it imparts to the hip, where there is no need for it, a rather heavy appearance.

Half-round Hip Tiles have the advantage that they are " time-savers " in fixing, the latter more so than the former. The half-round tile used on hips is really a ridge tile, and presents the most clumsy appearance of all.

In both these methods last referred to, the bottom tile must be supported by a 2 × ⅜-inch wrought-iron hook, which is screwed to the hip rafter and turned upwards at its bottom end. This adds to the heavy appearance already complained of. Both these tiles require bedding in mortar and pointing in cement

Methods of Finishing Eaves.—In order to give a pleasing appearance to a roof, the line of the roof is sometimes canted upwards as it approaches the walling. This alteration of angle is contributed by means of the addition to the feet of the rafters of a piece of rafter nailed to the side of the rafter and notched over the wall plate. This is termed a *Sprocket Piece.* The change in direction of the line of the roof or the alteration of the angle should not be too abrupt ; and in order to soften the angle at the change of pitch, the battens should be placed above and below the actual angle rather than in it. By this means a course of tiles will bridge the angle at about the centre of the exposed portion of the tile.



DETAIL OF FINISH AT SLOPING VERGE: THE WINCHESTER CUT

Fig. 212.

(*Courtesy of Clay Products Technical Bureau.*)

Pitch.—As to the matter of the angle at which a roof should be built to give the best appearance, this is possibly one of opinion ; though if one wishes to build in a characteristic style of the country in which the building is, there can be no doubt that a steep pitch is characteristic of our country. The real reason underlying the preference for a flat-pitched roof is more often than not a mistaken idea of economy. On the face of it, if the matter is considered mathematically, it is clear that less material is required for a flat roof than for one with a steep pitch. Yet actually does this amount to anything very considerable ? Possibly a foot or so in the length of the rafters, which when the extra timber, boarding, felt, battens, and tiling are estimated, may represent to some an unreasonable expenditure for what is after all a matter of opinion, *i.e.* whether steep roofs or low-pitched roofs look best.

If that were all there was to be said about the matter it might cause some surprise that anyone is ever found to build anything but a flat-pitched roof. However, it isn't.

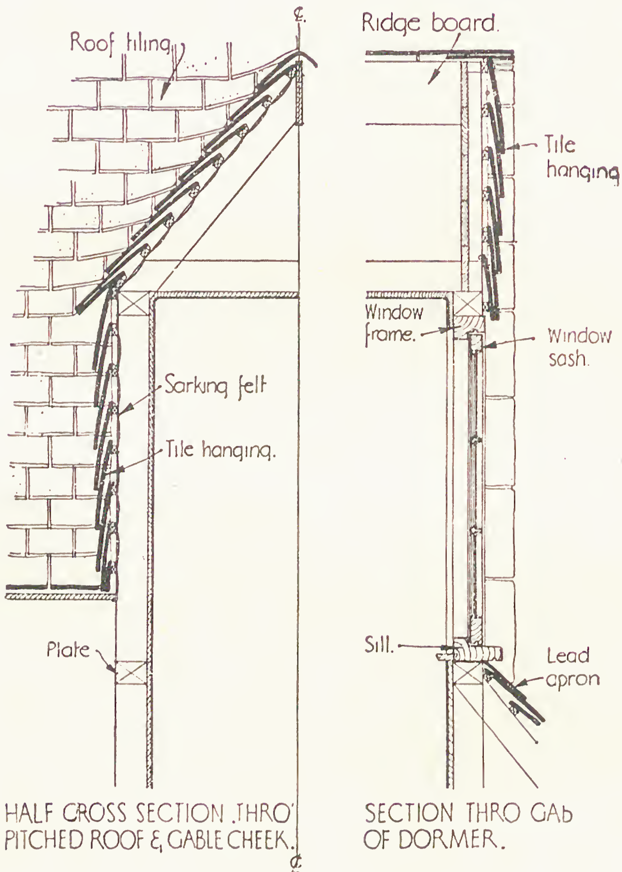


Fig. 213.
(*Courtesy of Clay Products Technical Bureau.*)

It should be considered what the purpose of a roof is, and why roofs in some countries are built with very steep pitches as in Sweden, for example, whilst in others actually flat roofs are found, as in India.

The purpose of a roof is, obviously, to protect the space enclosed under it from the weather; to act as a shade from the sun; and to exclude the wind, rain, and snow. Consequently flat roofs with wide eaves and verandahs have for so long become adopted. In northern countries, however, where not only a large rainfall but considerable weight of snow is to be expected in winter, the main necessity is to provide a roof that will not collect the snow to any great depth, and one that will shed the rain before it has time to collect and consequently to penetrate to any appreciable extent. Again, in a country where there is considerable snowfall and considerable power to the sunshine, such as Switzerland, it is found that both steep and flat-pitched roofs are favoured, and that whether steep or flat all have very wide projections to the eaves and verges, the reasons for the latter being the provision of shade and the shedding of the snow as it melts away from the upright walls of the building and their foundations.

For some reason, possibly ease in working and calculating, the steeper-pitched roofs are often formed at an angle of 45° ; and for some reason unknown, this angle never looks quite right, possibly because it is too geometrical. But whatever the reason, an angle just over or even just under 45° is preferable. A very satisfactory angle for the pitch of a roof is 47½° and for the sprocket 40°.

Roofs built in this manner, with a sprocket at a different angle from the main timbers, are termed "*Bell Cast*" roofs ; and with this form of construction the finish of the feet of the sprockets and the soffit of the eaves may present at first some difficulty. A very good finish is provided by attaching to the sides of the sprocket pieces of right-angled brackets out of 2 × 1 inch, having the upright member fixed to the face of the wall or to the wall plate and the horizontal member finishing flush with the bottom of the sprocket piece. These brackets may then receive either matched and V-shaped boarding, or they may be lathed to receive a plaster of lime and sand.

Note.—In either of the above methods of forming a soffit to the eaves ventilator gratings should be inserted, at least two in each straight run, to admit air to the spaces between the rafters.

A Fascia is fixed to the ends of the sprocket pieces and the gutters attached to this, or the gutter may be supported on brackets screwed to the sides of the sprockets.

The plastered soffit mentioned above forms a very satisfactory finish to a tile-hung wall and one that is very pleasing in appearance also.

Valleys in tile roofs are formed in the following ways :

(1) *The Plain Tiles are cut to Mitre* in the angle formed by the two roofs, and 5-pound lead soakers are interleaved and fitted into the angle. The tile cut to a mitre is cut from a tile and half where necessary, to keep bond with the plain tiling. The lead soakers used in this manner are kept shorter than the tiles, so that they shall not show. This method forms a very sound and watertight valley.

(2) *Open Lead Valleys* are formed in the angle by dressing lengths of 6-pound lead into the angle and finishing it at the sides over triangular 1 × ¾-inch fillets which the tiles rest on. Laps in the length of the lead should be at least 3 inches. This method makes a sound job, with the exception that on the steep pitches the lead is apt to creep when subjected to extremes of temperature.

(3) *Purpose-made Valley Tiles* are used. These are plain tiles made in the required shape to fit the internal angle and resemble a purpose-made hip tile used reversed, the nail holes for hanging being in the corners of the upper and wider ends of the tile.

(4) *Laced Valleys* are formed on an 11-inch valley board which is nailed to the hip rafter ; and on this board, tile-and-a-half tiles are nailed diagonally. The courses of the plain tiling are given a sweep upwards into the valley, so that the sides of the tiles next the diagonal tiles fit neatly. This forms an inexpensive method, quick in execution and

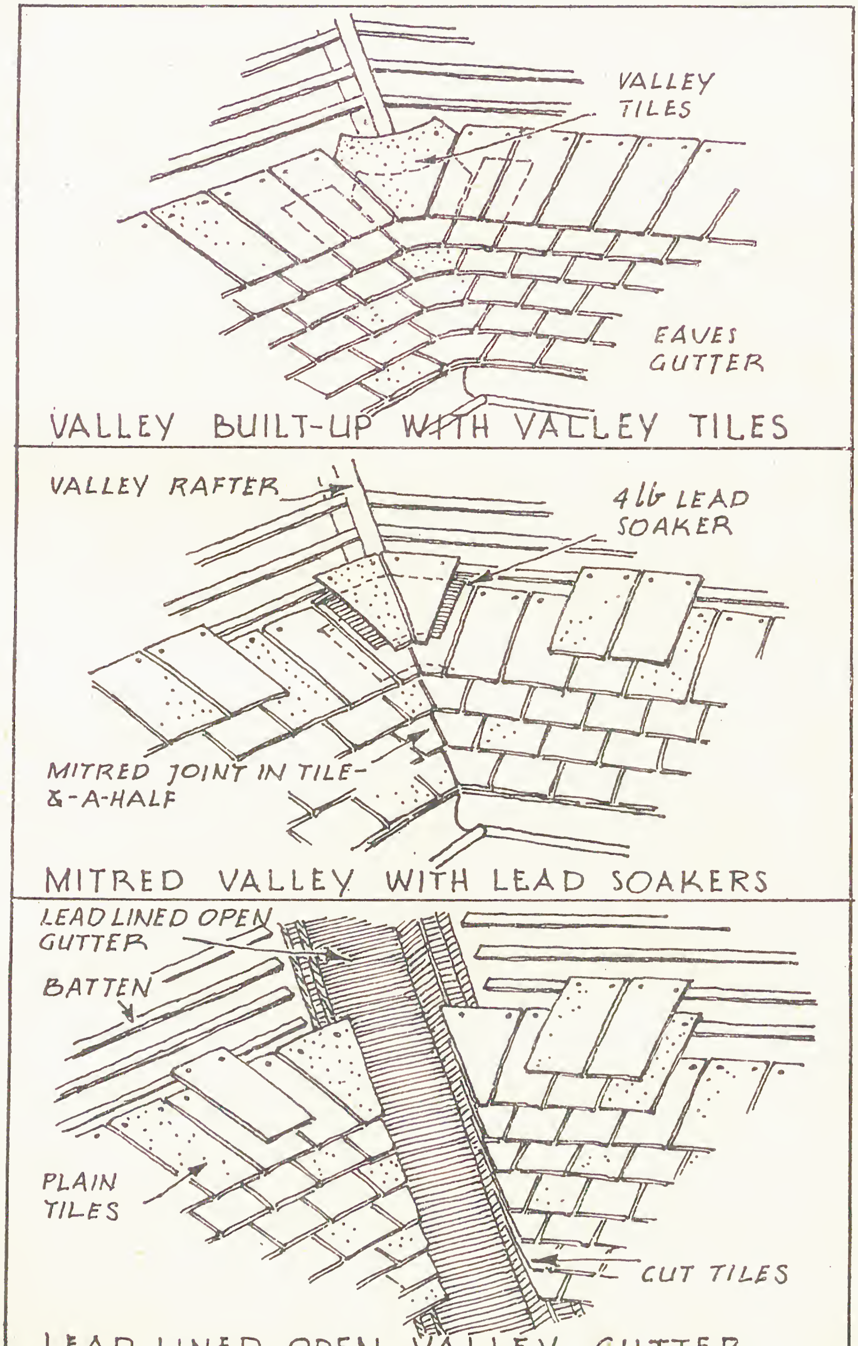

VALLEY TILES
EAVES GUTTER
VALLEY BUILT-UP WITH VALLEY TILES
VALLEY RAFTER
4lb LEAD SOAKER
MITRED JOINT IN TILE-&-A-HALF
MITRED VALLEY WITH LEAD SOAKERS
LEAD LINED OPEN GUTTER
BATTEN
PLAIN TILES
CUT TILES
LEAD LINED OPEN VALLEY GUTTER

Fig. 214.

economical of material, as no cutting is required. The diagonal tiles must be placed with the longest length leading right and left alternately. At the bottom of the valley the undertiling valley tile must have the angle cut off to form a rounded angle.

(5) *Swept Valleys* are formed in tiling in a similar manner to swept valleys in stone roofs. But this method is expensive, as it requires that the tiles should be cut to form suitable shapes to turn a quadrant curve in plan, or in other words, each tile in the quadrant curve has to be cut into a wedge shape, the lower courses have a small curve, the curve being increased up to the fourth or fifth course, when a cone-shaped curve is formed.

Other Uses for Tiles.—*Tiles* are also used in turning brick arches to form the keystone, as the slenderness of the tile enables the extra thickening to be given to the mortar joints at their top, without causing too wide joints.

Kneelers to gables are also formed in tiles corbelled out, one over the other, to give the required projection against which the gutter may be terminated.

Pantiles are sometimes used to form fascias backed by mortar and finishing up under the eaves.

Copings to Garden Walls are formed of half-round ridge tiles and pantiles, and are bedded on plain unribbed tiles set in cement. The appearance is heavy, and the projection unnecessary unless the wall under is formed of cob or some material from which it is particularly desirable to exclude the rain.

Encaustic Tiles are made of different clays, one being pressed into the other to give a variety of colour often inlaid to form a pattern. The whole is then burnt into one, and choice of suitable clays must be made to the end that each contracts equally in burning.

Paving Tiles are die-pressed sometimes with a patterned surface and a groove under-surface to give a key to the mortar on which they are bedded. A variety of colours are to be obtained, including buffs, reds, blues, blacks, and yellows. Quarries are 9 × 9 inches with a diamond pattern in relief.

Decorated Tiles are made from pugged clay or from semi-plastic clay. The decorations are applied in colour and burnt on before the glaze. "Overglaze" tiles have a less durable pattern, and are decorated above the glaze.

The Sizes of Floor and Wall Tiles are 9 × 9 inches; 9 × 3 inches; 6 × 6 inches; 6 × 3 inches; and 3 × 3 inches, all ½ inch thick. Paving tiles are 1 inch thick and upwards.

The tiles are priced by the 100, but are usually measured by the foot super, allowance also being made for cutting for any patterns, borders, or mouldings and skirtings to wall tiling.

Laying Tile Floors.—Tile floors are laid in halls, vestibules, sculleries, larders, and sometimes in kitchens, though it is complained that they are

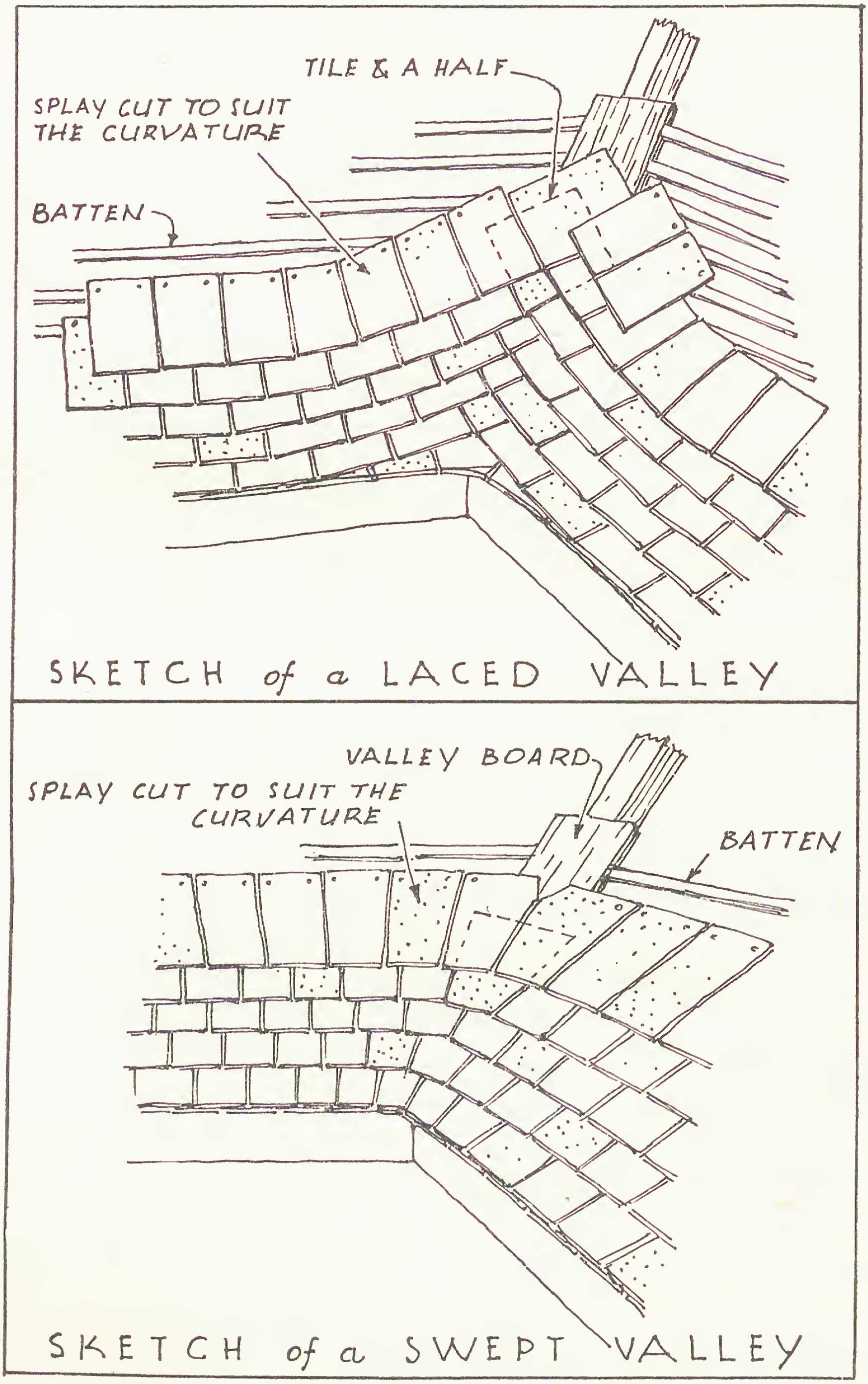

TILE & A HALF
SPLAY CUT TO SUIT
THE CURVATURE
BATTEN
SKETCH of a LACED VALLEY
VALLEY BOARD
SPLAY CUT TO SUIT THE
CURVATURE
BATTEN
SKETCH of a SWEPT VALLEY

Fig. 215.

tiring to walk on. Paths and verandah floors are also paved with the larger types of paving tile, or more generally paving bricks.

For interior floors the tiles must be laid on a bed of concrete and bedded in neat cement, the cement being pointed into the joints.

Tiled hearths in glazed tiles are bedded in Portland cement laid on a levelled concrete bed. The tiles should not be cut for this work, the size of the hearth and opening being designed of such dimensions that the tiles will fit. The cement floating and the tile require a thickness of $\frac{3}{4}$ inch, so that if the hearth is to finish flush with the wood floor, the concrete hearth must finish $\frac{3}{4}$ inch below the wood floor.

Method of Measurement.—Tiles are sold by the thousand, and are measured in squares of 100 feet super. For cutting, 5 per cent. should be allowed ; and though tiling and slating are frequently let to sub-

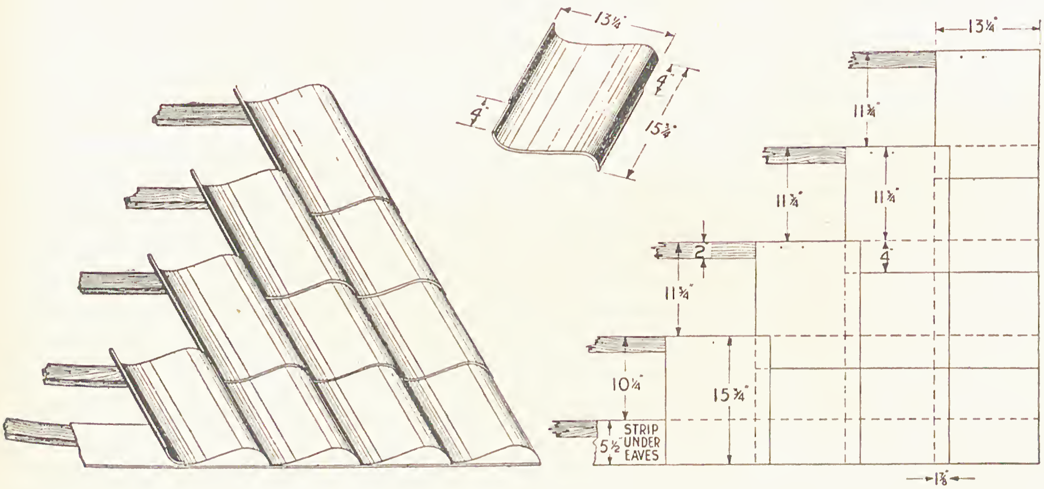


Fig. 216.—" Poilite " pantiles.

contractors, it is advisable that the builder should have a ready method of estimating the approximate quantity of either material that will be required for any roof.

Area.—It is generally taken that the area of any roof is the same, whether hipped or gabled, and so far as measurement alone is concerned, this is correct where all the pitches are the same ; but when the cutting required is considered, it will be evident that considerably more time will be spent in cutting for a hipped roof than for a gable.

To find the area of a hipped roof where the pitches of the hips is the same as that of the main roof, measure the length of the roof at the eaves and the length of the ridge, add these two dimensions together and divide by 2 : this will give the mean length. Then the total area of the two portions of the main roof will equal twice the product, the mean length multiplied by the *actual* length of the rafter when cut to the pitch ; and the total area of the two hip triangles will equal twice the product of half the width at eaves, multiplied by the actual length of the rafter cut to pitch. The two products added together will give the total area of this simple roof, and the method will be the same for more intricate roofs, the calculation requiring only to be done in sections and the results added.

If the roof is gabled instead of hipped, then the total area will be twice the product of the length at eaves by the length of rafter cut to pitch ; and the result will be found to be the same as that of the previous calculation.

The introduction of gables of the same pitch into a roof, whilst they do not alter the area of the roof, do, of course, considerably increase the cutting and labour. When a gable of the same pitch is inserted, it will be found by measurement to consist of two triangles, each exactly half of the area of the triangle they replace.

But where the gables are of a different pitch, the area of the total will be increased or decreased by the amount that the length of the rafters of the gables are greater or less than the length required for the rafter, had the roof been without gables.

It will often be found that hipped ends of a roof are pitched at a steeper angle than the pitch of the main roof. This is a good practice from the design point of view, as it gives the roof a better appearance—stronger, for one thing—than if the pitch of the hips is the same as that of the main roof. In this case the area of the roof must be worked out in sections and added together. It should be remembered that if the hipped ends are formed at a steeper pitch, the ridge of the main roof will be lengthened.

Note.—In working out these areas it should be noted that the rule employed is that the area of a parallelogram equals the length of the base, multiplied by the perpendicular height.

Hips on plan are always at an angle of 45°, when the pitch of the hip and the main roof are the same. Where a roof has a flat in the centre covered with lead, the area of the roof must be worked out as two separate portions, and the area of the centre strip less the flat added to the total of these two. For instance, if a roof 40 feet × 36 feet × 8 feet 6 inches high has a flat 12 feet wide in the length of 36 feet, the area will be :

2 (40 feet × 8 feet 6 inches) + 2 (12 feet × 8 feet 6 inches),

the second product being the area of the two sloping portions at each end of the flat, the area of the flat being omitted, as it is not tiled, and therefore for the present purpose not required in estimating the quantity of tiles required.

To find the actual length of a hip or valley the arithmetical formula is that the hypotenuse (sloping side) of a right-angled triangle equals the square root of the square of the base and the square of the height. Or more simply expressed in geometrical terms, the square on the hypotenuse of a right-angled triangle is equal to the sum of the squares on the other two sides.

Perform this operation practically by drawing a right-angled triangle, having for its base a length equal to the length of the hip line shown on the roof plan, and its height equal to the rise of the roof from wall plate to ridge. Join the ends of these two lines and the length of the line last drawn, *i.e.* the hypotenuse, will be the actual length of the hip rafter.

Tiling Data.—*Copper Nails* should be used in nailing tiles, as wire nails rust, not only resulting in staining the tiles, but in the nails themselves eventually breaking.

To calculate the Number of Tiles required to the Square.—Divide the area of the square in inches by area of the gauge, *i.e.* the exposed portion of one tile, and the quotient gives the number of tiles per square.

For example, to find the number of tiles required for a square to a 4-inch gauge:

$$\frac{\text{Area of square in inches}}{\text{Area of gauge}} = \frac{14400}{4 \text{ inches} \times \text{width of tile}} = \frac{14400}{4 \times 6\frac{1}{2}} =$$

$$\frac{14400}{26} = 552\tfrac{22}{26} = 553 \text{ tiles.}$$

Note.—Allowance must be made for cutting and waste.

Number of Tiles required per Square of 100 *sq. ft.*

Tile size inches	Gauge inches	Lap inches	No. of tiles per square
$10\frac{1}{2} \times 6\frac{1}{2}$	4	$2\frac{1}{2}$	550
,,	$3\frac{3}{4}$	3	590
,,	$3\frac{1}{2}$	$3\frac{1}{2}$	635
11×7	4	3	514
,,	$3\frac{3}{4}$	$3\frac{1}{2}$	550
,,	$3\frac{1}{2}$	4	588

Pantiles laid to—

Gauge of 10 inches = 180 pantiles.
Gauge of 11 inches = 164 pantiles.
Gauge of 12 inches = 150 pantiles.

A Square of Plain Tiling—

Weighs about 15 cwts.
Requires 1 bundle of laths.
Requires $1\frac{1}{2}$ hundred of nails.
Requires 1 peck of tile pins.
Requires 3 hods of mortar.

A Square of Pantiles—

Weighs about 8 cwts.
Requires 1 bundle of laths.
Requires $1\frac{1}{4}$ hundred of 6*d*. nails.

Table of Sizes and Weights

Plain Tile : 10 × $6\frac{1}{2}$ inches ; $2\frac{1}{2}$ pounds each ; $22\frac{1}{4}$ cwts. per 1,000.
Pantile : $13\frac{1}{2}$ × $9\frac{1}{2}$ × $\frac{1}{2}$ inch ; $5\frac{1}{4}$ pounds each ; 47 cwts. per 1,000.
Ridge tile, plain : length, 18 inches ; girth, 14 inches ; weight per 1,000 14 cwts.

NUMBER OF ORDINARY HIP OR VALLEY TILES REQUIRED PER 100 FEET RUN OF HIP OR VALLEY RAFTER

Pitch of roof.	Where ordinary plain tiles are fixed as follows :		
Degrees.	$2\frac{1}{2}$-inch lap.	3-inch lap.	$3\frac{1}{2}$-inch lap.
60	268	286	307 per 100 feet run.
75	258	276	295 per 100 feet run.
90	246	263	282 per 100 feet run.
105	235	251	269 per 100 feet run.
113	231	247	264 per 100 feet run.
120	227	243	260 per 100 feet run.

The hip rafter takes the same number of tiles as the common rafter, but if the length of the hip or valley rafter is measured, the figures in this table should be used.

For tiles, a 4-inch gauge is almost universally adopted.

Eave tiles : $5\frac{1}{2}$ tiles per lineal yard.

Tile-and-half Tiles (Gables) : These are used alternately, and $1\frac{1}{2}$ tiles per foot run of gable should be calculated. Usually about 40 tile-and-half tiles to 1,000 of ordinary plain tiles are required.

CHAPTER 13

SLATES AND SLATING

SLATE is a stone which has been formed by a muddy deposit. The chief chemical constituents of slate are clay and a certain amount of carbonaceous matter which gives it its dark colour. In the very early days of history clay was originally deposited under the water, and from the pressure imposed upon it in a vertical direction, that is, the weight of the water above, it was turned into shale. With the change of the earth's surface when the waters were replaced by dry land, there was considerable pressure and heat, but the pressure in this case was lateral. Hence in slate, there are found to be two distinct sets of planes: (1) the *Planes of Sedimentation* which were formed as the clay was deposited by the water and are therefore horizontal to the natural bed, and (2) the *Planes of Cleavage,* which are perpendicular to the planes of sedimentation. These planes of cleavage were caused by the lateral pressure and heat generated in the upheaval of the earth's surface mentioned above. When the lines of cleavage show on the face as curves, the condition of the material is described as " Yorky."

QUARRYING

Slate is obtained from quarries which are either: (1) *Open Galleries* on the surface of the earth, or (2) *Mined Chambers* under the surface.

The Mined Chambers are sunk in the veins of slate which are run down at an angle into the earth, exposing only their edges to the surface, and between these veins are strata of other kinds of soil or rock which divide the different chambers the one from the other, with the result that entrances have to be quarried into each separate vein of slate; but as these are sometimes 200 yards wide there is plenty of room for large mining chambers to be cut below, and from these the slate is hoisted to the surface.

The actual operation of cutting out the slate from the solid mass is more or less the same in the open quarries as in the chambers, and consists firstly of blasting, splitting, further splitting when hoisted to the surface, cutting into 3-inch slabs, and lastly in cutting into thin strips for use as slates upon a building.

The Penrhyn Quarry in North Wales is one of the largest surface quarries in the British Isles and possibly in the world. It is situated at a height of 1,500 feet above sea-level, in the Welsh mountains to the west of Conway.

and the quarry itself—in tiers—rises 1,200 feet from extreme top to bottom.

Seen from the face, the galleries rise one above the other in terraces from the quarry floor to the very top of the mountains, and the different strata of rock may be detected, standing out in distinct lines of colour and angles; here an occasional line of green slate, there a grey and grey-purple, serrated by a thin streak of bright quartzite from the deep broad vein of Penrhyn Blue Slate. A narrow layer of lava, grit, and mud rocks intervenes before there comes the Hard Red and Hard Blue Slate, which last is the oldest slate in the Cambrian formation.

The following notes are taken from an article descriptive of the Penrhyn Quarries which appeared in the *Quarry and Road Making*:

"The quarry itself is one of the wonders of Wales, and as one stands on an eminence, it suggests the appearance of a great Roman amphitheatre. . . . It forms a deep, curving cañon as it follows the slate vein, its sharply defined precipitous sides recalling pictures of the Colorado and the Yosemite Valley. From the quarry bed the galleries rise in steps; each step is somewhere near 60 feet high—with the height 1,500 feet above sea-level.

"The work of extracting the Penrhyn slates is carried on simultaneously in each of the twenty galleries. This system of quarrying away the rock and slate evenly over the whole side of the mountain prevents undercutting, or rather the fall or slide of rock from above as the result of diminishing or weakening the base. Each terrace or gallery is about 30 feet wide, and its rock face or wall, which is being quarried for its slate, is about 60 feet high. The slate is quarried in blocks by blasting and pneumatic drilling. Holes are bored for blasting, gunpowder being used, as the object is to loosen the slate without shattering it. Having thus loosened the slate, crowbar, chisel, and hammer suffice to extract and bring it down in great blocks or slices. Over and above the use of gunpowder every advantage is taken of the natural faults and joints in the strata of the slate to win it out with the least labour and in the biggest blocks. These are divided into convenient sizes for handling, and hoisted by pulleys into trucks, which are hauled by a fleet of 20 locos along rails to the trimming sheds, of which there are 17 on different levels. Aerial ropeways span the quarry, acting as travelling overhead cranes as well as conveyors. Incidentally, it may be mentioned that there are 50 miles of tramway lines in the Penrhyn Quarry, while a narrow-gauge railway carries the finished slates down to Port Penrhyn on the Menai Straits, whence the quarry's private fleet of five steamers ship the slates to all the leading ports of the United Kingdom, as well as to Continental ports.

"Shafts have been sunk through the rock from the main dressing floors to the level of the quarry floors, with which they are connected by tunnels. The 'cages' in these shafts ascend and descend by hydraulic power.

Each cage is integral with a water tank, and there are two cages to a shaft, one up and one down. Pumping water into the tank on the top cage causes it to descend, the lower cage tank being empty ; letting out the water when it gets to the bottom of the shaft and filling the tank of the cage at the top reverses the order of descent.

" All slate is taken from the quarry, both good and waste. At the dressing floor it is divided and the good either goes to the dressing sheds

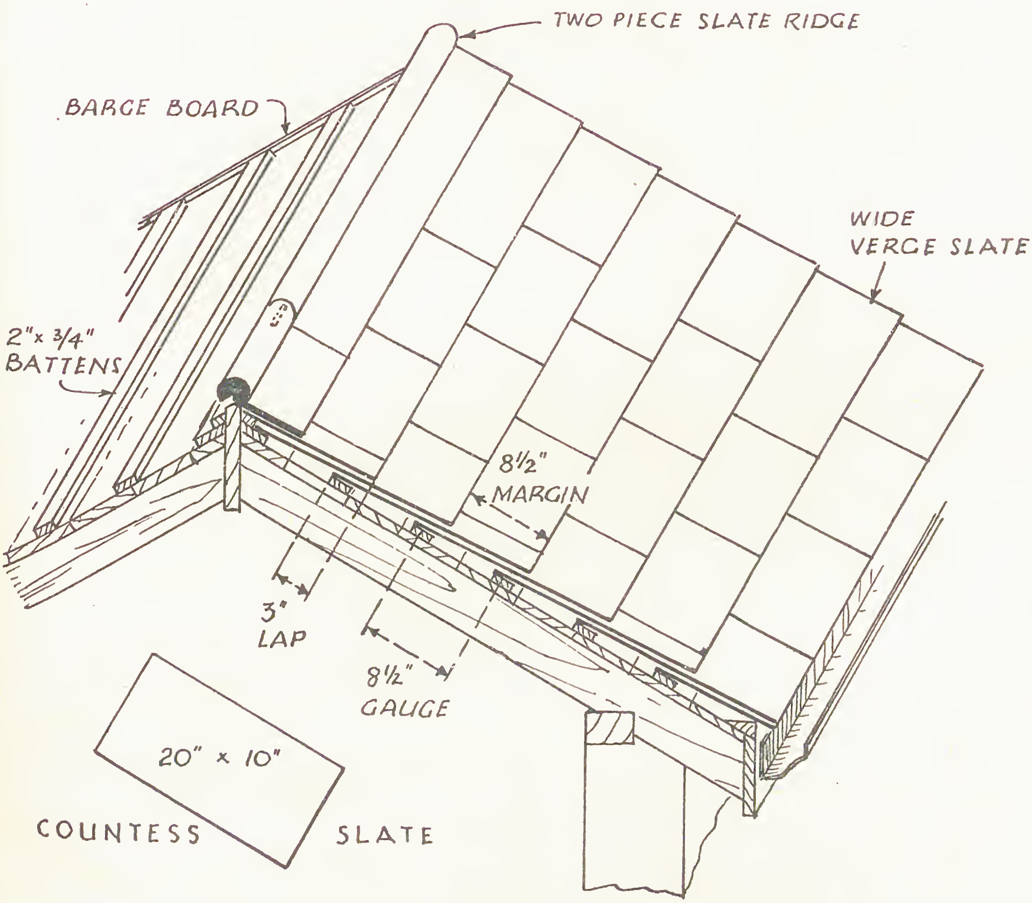


Fig. 217.—Slating (20 × 10 inches, 3-inch lap) head nailed.

or to the pulverising mill, to be ground down for subsequent manufacture as a by-product, while the waste goes out to the tips, to be dumped.

" The slate from the Penrhyn Quarry has been in use for building purposes for the last two centuries, and it is exported to every part of the world. As to durability, there are now standing in the neighbourhood of the quarry roofs that have endured the alternating mildness and severity of the North Welsh climate for at least 150 years without showing any signs of failure or decay."

Penrhyn slates are classified into Firsts, Seconds, and Thirds, the terms denoting difference of thickness rather than quality. They are classified into six shades of colour: blue, red, G.W., grey, grey mottled, and mottled and striped; though slate rock, being a natural material, varies only slightly in colour according to the situation of the veins, and it is perhaps rather misleading to label any section with the name of a distinctive colour. In size these slates range from 10 × 8 inches to 24 × 14 inches in over twenty stages. The size to which a roofing slate is dressed varies according to the natural formation of the rock. So that in ordering it is advisable to allow a certain latitude in this respect, and to specify say "in sizes 20 × 10 inches or 20 × 12 inches," or any other range of sizes that may be suitable.

The Composition of the Penrhyn Slate is as given in the chemical analysis below:

	Per cent.
Silica	55·30
Oxide of Iron	10·00
Alumina	24·84
Lime	0·36
Magnesia	2·46
Sulphuric Acid	0·21
Potash	1·47
Soda	0·53
Water of Hydration	4·70
Loss	0·13

The Absorption is given under:

	Per cent.
Penrhyn 1st Blue Slate	·020
Penrhyn 1st Red Slate	·019
Penrhyn 1st Grey Slate	·021

Concerning the above, it is claimed that it is quite possible that this average absorption of ·020 per cent. by weight is not absorption at all, as it is the practice in making the test not to dry the slate, after its immersion in water, for twenty-four hours, and that therefore the increase in weight may be due to water adhering to the surface.

For comparison, the analysis of various slates is given in the table at top of page 259.

Of *Underground* slate mines the Oakley Slate Quarry at Blaenau-Festiniog in North Wales is the largest in the world.

Here, five veins of slate are being worked simultaneously, partly open, but mainly underground. To gain access to the veins, underground shafts are driven in through the mountain-side and chambers are worked 50 feet wide by 50 feet to 60 feet high. The five veins enter the mountain at an angle of 45°, and are called in order of descent; North Vein, the Back Vein, the Small Vein, Main or Old Vein, and the New Vein. In these quarries there are fifty miles of railroad (mostly underground), eleven miles of compressed-air and water pipes, twelve large slate dressing-mills, with 500 saw tables and six hydraulic and electric pumps capable of raising 250,000 gallons per hour.

FIG. 218.—PENRHYN SLATE QUARRY. VIEW SHOWING TERRACES.

Fig. 219.—A "RANDOM-WIDTH" SLATED ROOF. SLATES OF REGULAR LENGTH AND GAUGE BUT IRREGULAR WIDTH.

Notice swept valley, mitred hip, and slate undercloak to verge.

(Courtesy of Setchell & Sons, Ltd.)

Analysis of Penrhyn Slate.	Per cent.	Analysis of an American Slate.	Per cent.	Analysis of a German Slate.	Per cent.	Analysis of a French Slate.	Per cent.	Analysis of Slate from another district of Wales.	Per cent.
Silica	55·30	Silica (SiO_2)	56·38	Silica (SiO_2)	59·35	Flint	48·60	Silica (SiO_2)	56·71
Oxide of Iron	10·00	Titanium dioxide (TiO_2)	·78	Titanium dioxide (TiO_2)	1·00	Alumina	23·50	Titanium dioxide (TiO_2)	·70
Alumina	24·84	Alumina (Al_2O_3)	15·27	Alumina (Al_2O_3)	13·56	Oxide of Iron	11·30	Alumina (Al_2O_3)	14·43
Lime (*CaO*)	·36	Ferric Oxide (Fe_2O_3)	1·67	Ferric Oxide (Fe_2O_3)	1·10	Magnesia	1·60	Ferric Oxide (Fe_2O_3)	1·98
Magnesia	2·46	Ferrous Oxide (FeO)	3·23	Ferrous Oxide (FeO)	4·75	Potassa	4·70	Ferrous Oxide (FeO)	3·65
Carbonic Acid (CO_2)	*Nil*	*Lime* (CaO)	4·23	*Lime* (CaO)	5·20	Water	7·60	*Lime* (CaO)	3·83
Sulphuric Acid (SO_3)	·21	*Magnesia* (MgO)	2·84	*Magnesia* (MgO)	3·60		97·30	Baryta (BaO)	·04
Potash (K_2O)	1·47	Potassa (K_2O)	3·51	Potassa (K_2O)	1·77			*Magnesia* (MgO)	3·47
Soda (Na_2O)	·53	Soda (Na_2O)	1·30	Soda (Na_2O)	1·48			Potassa (K_2O)	2·61
Loss on Ignition	4·70	*Carbon dioxide* (*CO_2*)	3·67	*Carbon dioxide* (*CO_2*)	4·45			Soda (Na_2O)	2·59
Loss	·13	Pyrite (FeS_2)	1·72	Manganous Oxide (MnO), Phosphoric Oxide (P_2O_5), Sulphuric Oxide (SO_3)	·31			*Carbon dioxide* (*CO_2*)	3·71
	100·00	Water above 110° C. (H_2O)	4·09	Water (H_2O)	3·41			Carbon (C)	·77
		Carbon (C)	·59		99·98			Manganous oxide (MnO)	·06
		Sundry and water, below 110° C.	1·11					Phosphoric Oxide (P_2O_5)	·05
			100·39					Sulphuric Oxide (SO_3)	·12
								Water (H_2O)	2·74
								Pyrite (FeS_2)	2·64
									100 ·10

The chemical analysis of this slate is given under :

	Old Vein. Per cent.	New Vein. Per cent.	North Vein. Per cent.
Silica	55·25	53·40	55·75
Alumina	24·60	26·67	26·20
Iron Oxide	10·40	9·53	10·00
Lime	1·00	0·90	0·86
Magnesia	2·09	1·85	1·77
Loss on Ignition . .	4·62	4·47	4·77
Alkalis	2·04	3·18	0·65

The Absorption Test after immersion for 2½ hours at 60° F. gave no appreciable increase.

The Weight per cubic foot per ton is 1 ton per 12½ cubic feet, and the crushing weight, 21,000 pounds per square inch ; taken on a slab 4 feet × 1 inch with 1 foot bearing under a load of 783 pounds.

From the above analysis it will be seen that this slate is practically free from lime, and consequently it is not affected by acids and other chemical pollutions found in the atmosphere in the neighbourhood of cities and manufacturing districts.

The colour is a rich smoke grey, which remains unaltered by rain, frost, heat, and impurities in the air.

This mine has been in operation for two hundred years, though at first as an open quarry on the hillside, and many of the buildings erected at that time still retain their original slate roof.

The Size and Quality of slates in general are defined by the terms, Best, Mediums, and Seconds, or First, Seconds, and Thirds—these terms having reference to the texture, thickness, and uniformity of cleavage. The usual average sizes of " Bests " are from 12 inches to 18 inches wide, to 22 inches long, but it is customary to grade slates in accordance with their sizes, when they are known by the various names as given in the table below, which also gives the number of slates required per square.

NUMBER OF SLATES REQUIRED TO COVER A SQUARE (100 SQUARE FEET)

Name.	Size in inches	Number.		
		2-inch Lap.	3-inch Lap.	4-inch Lap.
Empresses	26 × 16	75	78	81
Small Empresses	26 × 14	86	89	93
Princesses	24 × 14	93	98	103
Duchesses	24 × 12	109	115	120
Small Duchesses	22 × 12	120	126	133
Marchionesses	22 × 11	131	138	145
Wide Countesses	20 × 12	133	141	150
Countesses	20 × 10	160	169	180
Countesses	18 × 12	150	160	171
Countesses	18 × 10	180	192	205
Viscountesses	18 × 9	200	213	228
Viscountesses	16 × 12	171	187	200
Viscountesses	16 × 10	206	221	240
Ladies	16 × 9	228	246	266
Headers	16 × 8	257	277	300
Headers	14 × 12	200	218	240
Headers	14 × 10	240	262	288
Headers	14 × 8	300	327	360
Headers	14 × 7	343	374	411
Headers	13 × 10	262	288	320
Headers	13 × 8	327	360	400
Headers	13 × 7	374	411	457
Headers	12 × 10	288	320	360
Doubles	12 × 8	360	400	450
Doubles	12 × 6	480	533	600
Doubles	10 × 10	360	411	480
Doubles	10 × 8	450	514	600
Doubles	10 × 6	600	686	800

The Thickness varies from $\frac{1}{6}$ inch to $\frac{3}{16}$ inch for bests ; $\frac{3}{16}$ inch to $\frac{1}{4}$ inch for seconds, and from $\frac{1}{4}$ inch to $\frac{3}{10}$ inch for thirds.

The slates most generally used on buildings are " Countesses " and " Duchesses."

Slate for use as a roofing material is cut to a gauge from above, the top of the cut being in consequence clear cut, and the underside rough. This underside is the back of the slate. Punching and drilling for the nail holes is performed on the building in the manner described later.

FIG. 220.—PENRHYN SLATE QUARRY. BLASTING FROM THE FACE.

Fig. 221.—PENRHYN SLATE QUARRY. CUTTING THE BLOCKS.

A GOOD SLATE

The distinguishing features of a good slate for roofing purposes are :

(1) That it should have been split along the lines of cleavage.
(2) It should be hard.
(3) It should be tough.
(4) It should have a uniform colour (or brindled in some slates).
(5) It should give out a clear ring when struck.
(6) It should not be greasy.
(7) It should not have an absorption of more than $\frac{1}{200}$ its own dry weight.

VARIETIES OF SLATE

As has been stated, the most prolific slate areas are in Wales, and embrace :

The Carnarvonshire Quarries, including Penrhyn, Bangor, Bethesda, Dinorwic, Llanberis, produce a very durable, smooth, thin slate of purplish blue colour.

The Merionethshire Quarries, including the Oakley, Bettws-y-Coed, Blaenau-Festiniog, which are of a bluer colour than the Carnarvonshire slate.

The Old Quarries in England are the Delabole Quarries in Cornwall, from which is produced a very durable, strong, and light grey-blue slate and also rustics of green and brown and red. The slates are supplied in ungraded quantities known as " randoms."

Other Slate Quarries in England are the :

Westmorland (the Lake District), which provides a slate of a variety of shades of green, due to iron oxide and magnesia. These slates are thicker and coarser and more expensive than the Welsh slates, being $\frac{3}{8}$ inch in thickness.

Somerset (Wellington) provides a deep blue slate which, owing to its comparative softness and earthy nature, is more suitable for use in thick slabs than for roofing.

Of the **Scottish Quarries** those of *Aberdeen* provide a coarse blue-grey slate ; of *Argyll* a blue and rather absorbent slate ; and of *Perthshire* blue-greens, green, and greys of medium quality.

Irish Slates are dark blues and greys, and from abroad *Foreign Slates*, though not much imported, are to be obtained from America and Canada, Germany, Norway, and Portugal. These are mostly of inferior quality and generally of a blue colour.

Tilestones and Grey-stone Slates are produced from a sandstone rock, split $\frac{3}{4}$ inch thick, and used mostly in conjunction with stone roofing, rather than with slates, an objection against their use being their weight.

DEFINITIONS OF TERMS

The following terms are used in conjunction with slates, and are necessary to be understood before the description of the methods of laying slates on the roofs of buildings may be satisfactorily understood.

The Back of a slate is the *upper* surface when laid and not the under surface as might be reasonably expected. The *under surface* is termed the *Bed*.

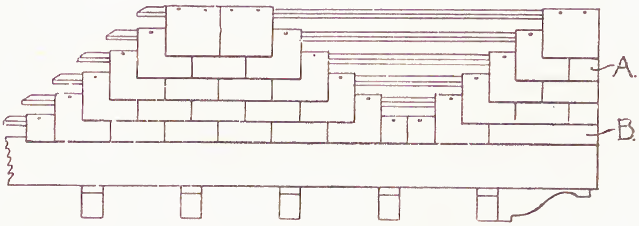


Fig. 222.—Method of forming verge.
A = half slate.
B = slate-and-a-half.

The Head is the topmost edge of the slate when laid, whilst the *Tail* is the bottom edge when the slate is in that position.

The Gauge is the distance between tail and tail of two adjacent slates when laid.

The Margin is that portion of slate which is exposed when the roof is covered with slate. This is also termed the *Weather*.

The Lap is the distance covered by a treble thickness of slates, and is usually from 3 inches to 4 inches. *Note*.—This subject, together with that of the gauge, is more fully dealt with on pages 265 and 266.

Pitch.—The pitch of a roof is the ratio of the rise to the span, and is described in degrees, as a 30° pitch, or in fractions, as a $\frac{1}{4}$ pitch, for example.

The pitch suitable for slate roofs is determined by the size of the slates—the smaller slates permitting of steeper pitches than the larger. Thus small slates are suitable for pitches of from 33° to 45°; ordinary slates from 26° to 34°, and larger slates for pitches so flat as 22°.

Slates form a more suitable roof covering for the flatter pitches, because owing to their thinness they can be laid with a lighter fit or bond, and the wind cannot obtain the same purchase under their tails as with a thicker material such as tiles, for example.

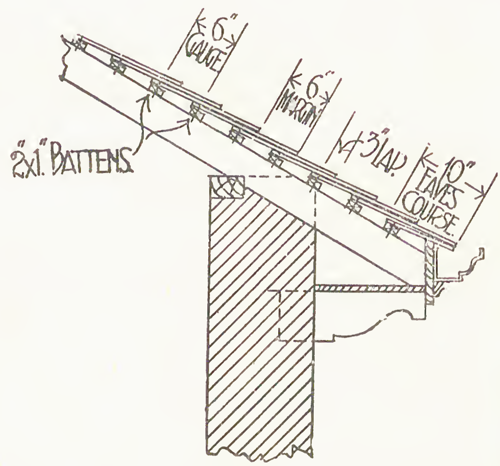


Fig. 223.—Definitions illustrated.

Nails and Nail Holes.—Each slate is pierced with two nail holes, and the nails used are of copper, zinc, composition, or iron. The composition, an alloy of copper and zinc, forms the best nails. The size of the nails required varies from $1\frac{1}{2}$ inches to 2 inches according to the size of the slate.

A Tilting Fillet is a triangular fillet fixed under the eaves course and at verges, in gutters, valleys, and also against vertical brickwork or masonry.

A Fascia is an upright board replacing the tilting fillet at the eaves, and is fixed to the feet of the rafters or the sprockets and carries the gutter.

The Ridge Course is the topmost course of slates, and is laid double with a shorter slate on top to cover the nail holes of the course below.

The length of this shorter slate equals the length of an ordinary slate minus the gauge.

Perpends are the linings vertically one under the other of the side joints of alternate courses of slating. The courses are laid in straight lines, so that the tails are horizontal and continuous.

Open Slating.—Slates are described as " Open " when they are fixed with their sides 2–3 inches apart. This method is economical for out-buildings.

Torching is the term used when the slates are laid on the battens with their undersides rendered or plastered with hair mortar.

Cutting and Waste.—At all intersections, such as ridges, hips, valleys, against chimney stacks, dormer windows, skylights, gable ends, there is a certain amount of waste in cutting the slates to the required shape to fit. This must be allowed for in estimating.

Slates are said to be *Close Cut* when butted to form a tight joint to a ridge or a hip formed without a ridge or hip slate or tile. When so close cut they are usually covered with lead or zinc.

Verges.—Wider slates are used in alternate courses in forming verges. The underside should be formed with a slate *undercloak* and the edges pointed in cement.

Eaves.—In forming the eaves a double course is laid with the under slates reversed and of a length equal to the length of an ordinary slate—the gauge.

Ridges and Hips are generally formed of tiles, and are as described under " Tiling." The wings of these tiles should be not less than 6½ inches, and be bedded in hair mortar and jointed in cement. Ridges are also formed in lead over a wood ridge roll, and sometimes a special form of slate roll is used.

Shouldering is the term given to bedding the top of the bed of the slate in a 2-inch strip of hair mortar. This method is used only in very exposed positions in which there is considerable wind, to prevent the driven rain from gaining access to the underside of the slating.

Rendering is the application of hair mortar to the underside of a slated roof when the slates are fixed to battens with no boarding. The object of this treatment is in theory the same as that of the last described, but in practice the result is found to be the attraction rather than the repulsion of moisture. In principle it is never sound construction to completely bed any timber in mortar, as this prevents the air from getting to it and so drying it out.

The Eaves are the first-laid portion of the roof starting from the rainwater gutter. The eaves are given a projection out from the face of the wall, the extent of this projection depending upon the style of the building.

However, speaking generally and with due regard to the economies of building, the greater this projection is, the better for the wall below, as its main purpose is to protect the wall below from falling rain. In certain districts a secondary purpose of wide eaves is to cast deep shadows, and in sunny climates a projection as deep as even 3 feet is given.

In order to shoot the rainwater from the roof direct into the gutter, the slating is continued over the inner edge of the gutter, *i.e.* the edge against the rafter feet. The projections may be formed in a variety of ways: by fixing a sprocket piece to the feet of the rafters; by building out corbel courses of brickwork or tiles; or by forming a cornice, the top of which is the gutter moulded to design. The rafter feet or sprocket feet may be fitted with a fascia board, or the gutter attached to them by wrought-iron brackets screwed to their sides. But whatever method of giving this projection is chosen, it is customary to lessen the pitch of the roof at the bottom just before it reaches the gutter, and so to give it a sweep upwards. This is generally done by fixing a tilting fillet at the bottom of the rafter ends, or the same result may be gained by raising the fascia board so that its top edge is slightly higher than the roof boarding.

It is a general principle in roofing with slates that, where there is any difference in the thickness of the slates, the thickest should be fixed in the lowest courses. The lowest course is laid with a double layer of slates in what is termed "a doubling eaves course," the lower, or first-laid course, is shorter than the ordinary slate length, being about

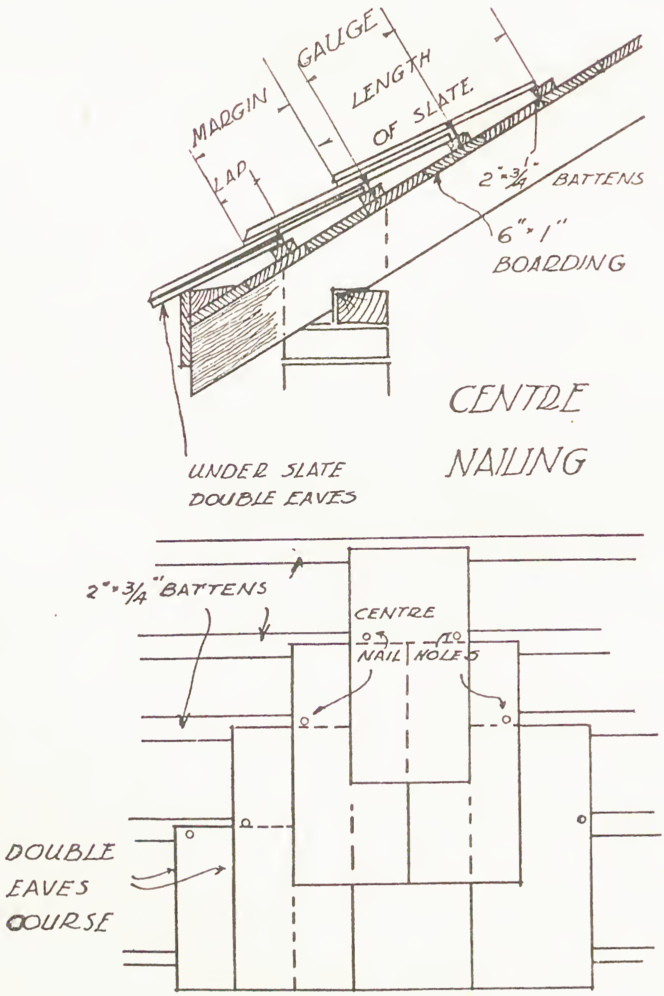


Fig. 224.—Centre nailing: fixing slates.

1 inch longer than half the ordinary length, or more accurately stated, the length of this course is the gauge plus the lap plus 1 inch. The course next is laid over this in the ordinary manner, though in centre nailing two battens are required close together, the bottom one being for the bottom course, which is nailed near its head, and the batten above for the centre nailing of the full-length slate above.

Double Slating is also inserted at the ridges, the top course being nailed close to the board. And the verges require a special slate $1\frac{1}{2}$ times the width of the ordinary slate.

NAILING

Slates are nailed in either of the two following ways:

Centre Nailing, in which the holes are pierced slightly above the vertical centre of the slate in order to clear the head of the slate beneath.

The Lap in centre nailing equals the distance between the tail of the uppermost slate and the head of the undermost slate at that point. *The Gauge,* in centre nailing—

$$= \frac{\text{length of slate} - \text{lap}}{2} = \text{for a Countess slate } \frac{20 - 3}{2} = 8\tfrac{1}{2} \text{ inches.}$$

The Advantages of Centre Nailing are that it is a more economical method, and affords less leverage to the wind.

Head Nailing is the method by which two nails pierce the slate at a distance of 1 inch from the head and $1\frac{1}{4}$ inches from the sides.

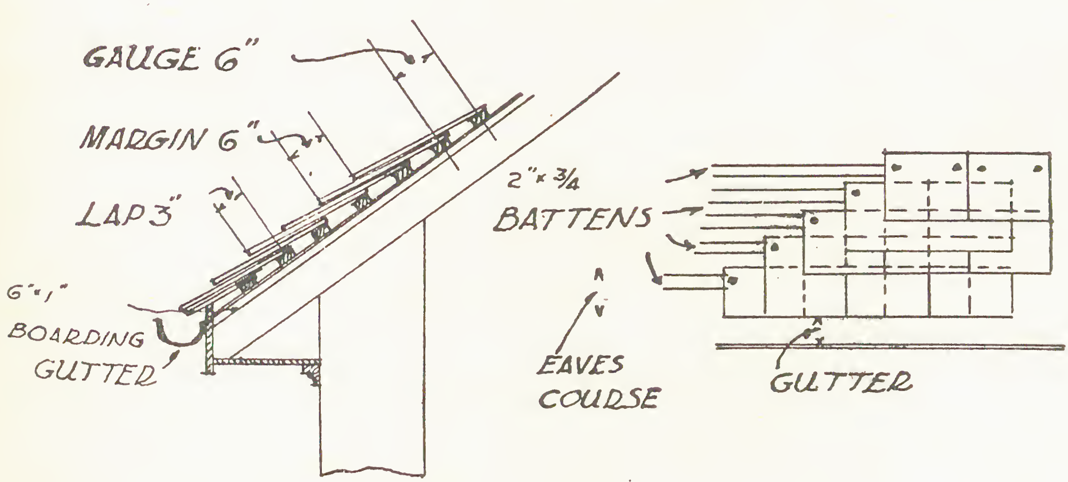


Fig. 225.—Head nailing.

The Lap in head nailing equals the distance between the tail of the uppermost slate and the nail hole of the undermost slate at that point. Generally 3 inches.

The Gauge in Head nailing—

$$= \frac{\text{length of slate} - \begin{matrix}\text{(lap + distance of nail}\\ \text{hole from head)}\end{matrix}}{2} \text{ for a Countess slate} = \frac{20 - 3 + 1}{2}$$

$$= 8 \text{ inches.}$$

The Advantage of Head Nailing is that it affords a thickness of two slates over the nails. Thus, if the uppermost slate becomes broken, the nails are not exposed to the weather and to consequent rusting and eventual breaking.

SPECIAL USES FOR SLATE

Slate Hanging.—Slates are also hung vertically to walls, either over brickwork on studding, generally as a preventive measure against damp. When hung over brickwork the length of the slate chosen should be such that the gauge will be a multiple of the height of the brick courses so that the nails may then be driven in the mortar joints. The brickwork may alternatively be battened, the battens being fixed at the proper gauge to afford the required margin or exposed surface. This may be greater than in roofing—a lap of $1\frac{1}{2}$ inches being all that is required.

The battening for slate hanging over brickwork may be either a single thickness of horizontal battens, or it may consist of counter battening, in which vertical battens are first fixed to the brickwork and horizontal battens then nailed to these as before.

On framework the battens are fixed horizontally, as on brickwork, at the required distance apart.

Though slates do not allow of such an extreme curve as is given in a bell-cast tile-hung wall, yet some kind of projection should be given to the bottom courses of any slate hanging. This may be afforded by shaping strips of wood curved outwards and fixed under the horizontal battens, or by corbel courses in brickwork.

Dormer Cheeks are frequently hung with slates, when the courses on the vertical portion of the dormer should be made to line with those on the roof.

Other Uses for Slate are the following :

Larder Shelves are best when formed of slate slabs, and for this one of the softer slates may be used as being more economical. Bangor slate is the best—and should be sawn ; self-faced slabs are more economical, being split at the quarry. For best-class work the surfaces may be planed, planed and rubbed, or planed, rubbed, and sanded, and if still further finish is required, they should be oiled.

The shelves should be from 1 inch to $1\frac{1}{4}$ inches thick, and of the required width and in single lengths wherever possible. If joints are found to be necessary they should be splayed and jointed with red-lead cement, and the supporting brackets should come under the joints. These brackets may also be of slate, and the slab should be pinned into the wall at back and ends.

Cisterns used to be built in slate slabs, though the practice is not so much in vogue at the present day The joints are made in oil mastic cement, grooved and secured by $\frac{5}{8}$-inch diameter wrought-iron galvanised bolts, with heads, nuts, and washers. Holes must be cut for supply and waste pipes.

Large rainwater storage tanks may also be formed in slate.

Urinal Divisions are formed of slate slabs attached to slate backs by pairs of $\frac{3}{8}$-inch brass angle plates $3 \times 3 \times 2$ inches, each pair being secured by two $\frac{1}{2}$-inch gunmetal bolts with heads and nuts, and four

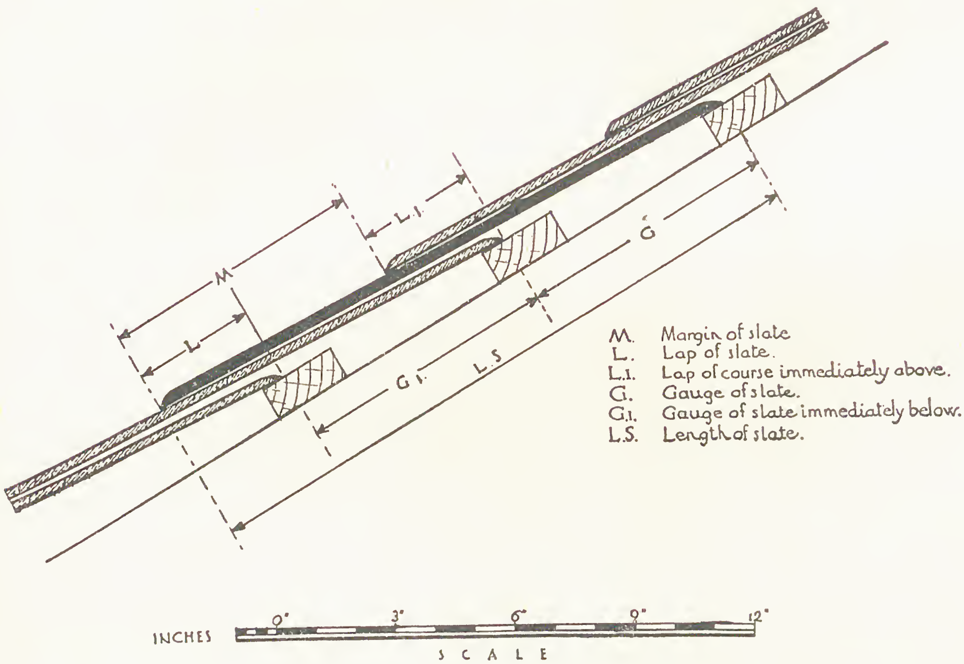


Fig. 226.—Illustrating lap, gauge, and margin in random slating.

$1\frac{1}{4}$-inch gunmetal screws. This use has been largely superseded by enamelled brickwork and terrazzo.

Urinal Channels are sometimes carried out in slate, though here also glazed stoneware has mainly superseded its use. The channel in slate would be 9×4 inches, and sunk to fall towards the outlet, where it should have a perforated outlet and be fitted with a brass urinal grate bedded in cement.

A New Use for Slate.—Recent developments in the treatment of the surface of slate in enamelling and polishing have made its use possible for a variety of interior purposes, where its decorative effect is a consideration and for which the use of slate in its ordinary untreated natural state would have been prohibitive.

The durability of slate for such a purpose as a wall covering will be

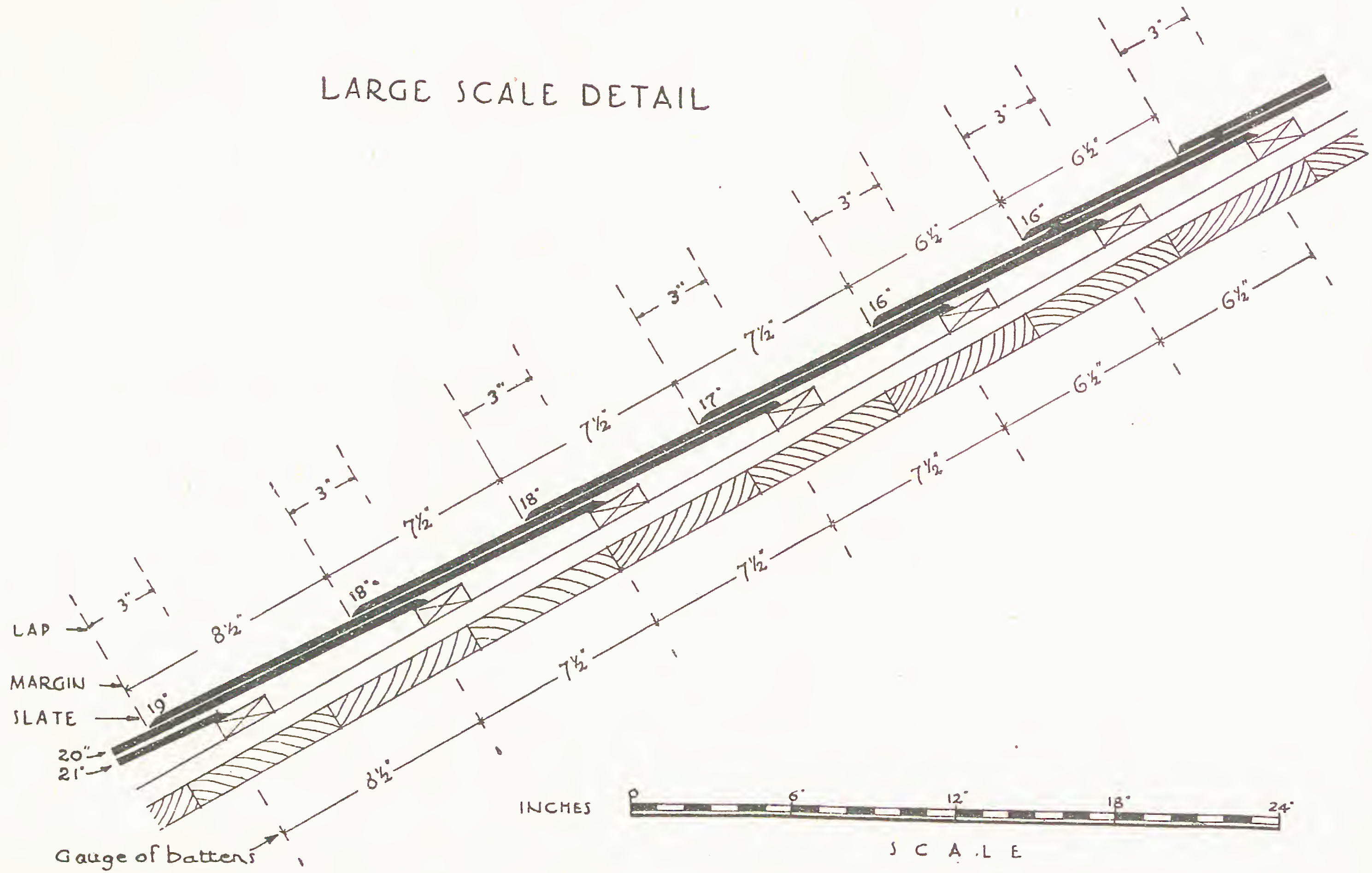


Fig. 227.—Detail of portion of example of random slating on the Delabole system.

recognised, and in the search for a wall covering that will not chip or crack with usage or changes of temperature, slate is supreme.

Whilst, as has been said, there could be nothing less interesting for interior finish than the blue tint of natural slate, since recent discoveries have made it possible to impart finishes representing polished mahogany, Italian marble, and even a lustre tile, the possibilities of interior detail now afforded by slate have been much increased.

The process is a patent one, and the finishes imparted are marketed under proprietary trade names. It consists in spraying liquefied metal from a spray-gun, and then treating the metal with alkalis to give variation to the basic colour.

TOOLS USED IN SLATING

The Tools used in slate roofing are few and simple, consisting of the cutting-iron or dressing-iron ; the pick-hammer ; the axe or zax ; the ripper ; the gauge, and the chalk line.

The Cutting- or Dressing-iron is a knife-edged piece of steel having two ends or spikes on its bottom edge for fixing into a block of wood. The upper or knife edge is sharpened, and the slate is laid across this on a line previously marked, to be cut to any required length or shape by means of the axe or zax. The part of the slate to be retained is held in the left hand, and the waste extends over to the right-hand side of the cutting-iron. The cutting away to the line is performed with a chopping motion with the axe held diagonally to the cutting line. The cutting-iron is generally 1 foot 6 inches long and the blade-edge portion, 2 inches deep $\times \frac{1}{4}$ inch thick and sharpened on its upper edge. The spikes are at the ends of the blade, and, pointing downwards, are sharpened to pierce the wood into which they are stuck.

The Axe or Zax, as has been explained above, is used for cutting the slates to any required size or shape, by dressing along the edges of the slate. It consists of a steel blade 12 inches long, sharpened on one edge, and having a sharpened spike on the back or upper edge. The blade is bent before entering the handle to afford facility for working closer to the line marked on the slate ; and the spike on the back is used for piercing the slate for nail holes by a quick turn over in the hand of the slater.

The Pick-hammer is used for nailing the slates into position on the roof, its pointed end being used in a similar manner to the spike last described, for punching nail holes. On the side of this hammer head there is a claw for extracting old or bent nails.

The Ripper is an all-metal tool used for removing broken slates and mostly in repair work. It is shaped into a thin flat steel blade, bent at one end into a handle, to raise it from the plane of the slate surface, and widened out at the other end to form two flat hooks for withdrawing or cutting the nails. The method of use is to slip the hooked end under the slate which it is required to remove, to juggle the hook round the nail,

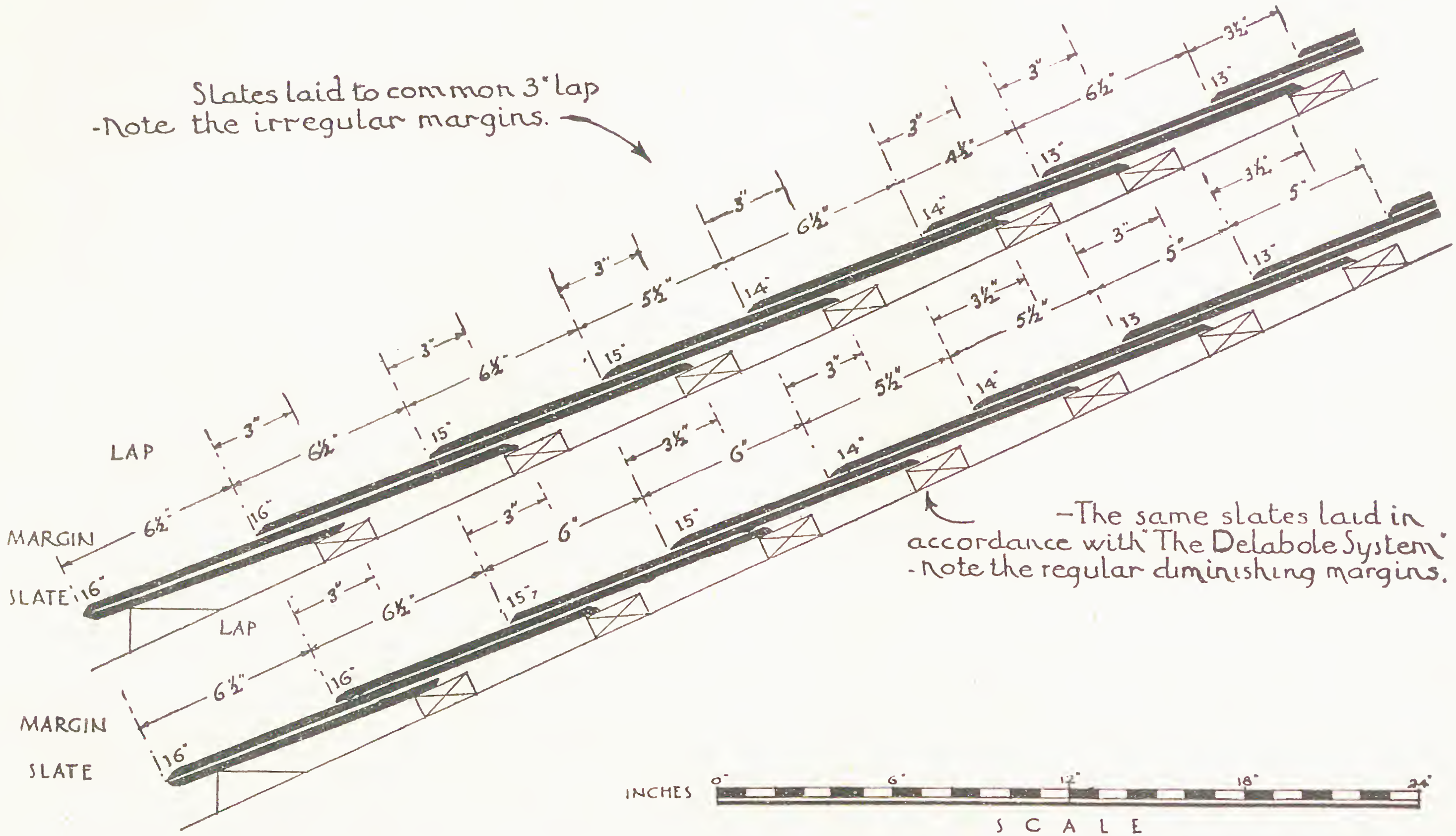


Fig. 228.—(Top) Random slates laid to common 3-inch lap. (Bottom) The same slates laid in accordance with the Delabole system.

and then to jerk the nail out or to break it. The slate will then come away.

The Chalk Line is similar to that used by the bricklayer in regulating his courses. After having been chalked, it is laid on the roof boarding, or where there is no boarding across the rafters, and a chalk line is transferred to the roof by snapping the line after it has been stretched tight and either held down or fastened in the desired position.

These chalk lines give the positions of the bottoms of the battens, and are distant apart the length of the gauge minus the width of the batten.

The Gauge is a piece of a batten having nails piercing it and with their points projecting, and is used to mark the lines for the nail holes on the back of the slate.

METHODS OF PREPARING A ROOF FOR LAYING SLATES

Battens.—The battens to which the slates are nailed are from $1\frac{1}{2}$ inches to 3 inches wide by $\frac{3}{4}$ inch to 1 inch thick—$2 \times \frac{3}{4}$ inch being the most usual size.

The chalk lines above referred to, and consequently the battens, are spaced the specified gauge distance apart, with the exception of the extra batten required for the eaves under the slate already referred to.

TABLE GIVING DISTANCE OF BATTENS

Length of Slate Inches.	3-inch Lap. First Batten. Inches.	3-inch Lap. Remaining Battens. Inches.
24	11	$10\frac{1}{2}$
22	10	$9\frac{1}{2}$
20	9	$8\frac{1}{2}$
18	8	$7\frac{1}{2}$
16	7	$6\frac{1}{2}$

Alternative Methods of preparing a roof for laying slates are :

Board and Felt, in which 6×1-inch boarding is laid on the rafters and covered with asphalted roofing felt or Willesden paper, given a 3-inch lap at the joints and tacked.

Thicker Boarding will be found to be required when the slates are nailed direct on to the boarding, as the nails being 2 inches long will penetrate the boarding and stick through on the underside.

Board Felt and Batten.—In this method the battens are added over the felt or paper, and fixed horizontally as already described.

An Improved Method is to insert 2×1-inch counter-battens up and down the roof from ridge to eaves over the felt and under the ordinary cross battens. An additional advantage in a roof formed in this manner is that an air space is provided between the slates and the felt. It could be improved still further if the felt were fixed between the two layers of battens and stretched tight, as in this way the felt would not rest on the roof boarding.

When *Concrete or Hollow Clay Tiles* are used to form the under roof, as in modern office and municipal buildings, the slates over are nailed to battens fixed to wood plugs let into the concrete or the joints.

In *Steel Roofs* principals are carried in stirrups to nail the battens to for slate roofing.

Flèche.—In slating a flèche a narrower slate is required according to the dimensions of the circumference of the flèche—the less the circumference the narrower the slate. The size of the slates should also decrease from bottom to top of the flèche. The bottom course will generally be finished on some form of cornice or table mould, and the top is often terminated with a ventilator or base for a weather vane. These will be formed in wood and the slates finish against them.

Delabole slates are frequently used for this purpose, owing to their small widths and random nature.

Ladder Hooks.—Ladder hooks $\frac{1}{2} \times \frac{3}{4}$ inch of 18 inches girth should be used for the support of ladders in repairing slate roofing. These should be screwed to the back of the rafter with 2-inch stout screws.

Angle Brackets are also used in forming landings for the slaters and for the slates to stand on. These are laid on the completed slating and fixed to the ladder hooks mentioned above.

Stone Slates.—Where these are used, longer nails are required, and for this type of roofing battens in addition to the boarding must be used.

ASBESTOS-CEMENT SLATES

These slates are manufactured from a mixture of fibrous asbestos and Portland cement. The material is hard and durable, and has high resistance to weather and the polluted atmosphere of industrial districts.

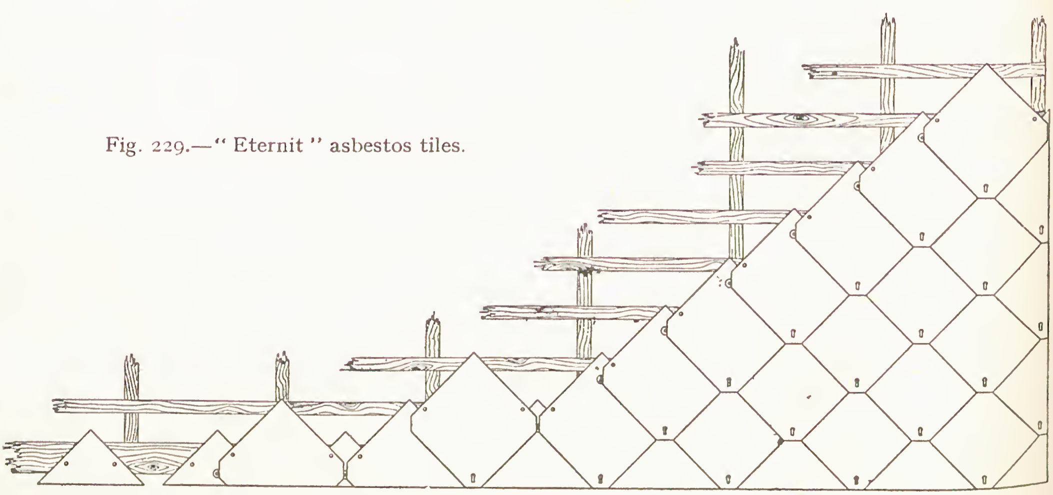


Fig. 229.—" Eternit " asbestos tiles.

Asbestos-cement slates are only half the weight of natural slates. They are thus easier to handle and transport, and economy in roof construction can be effected.

The natural grey colour is not attractive, but blue, red, and russet-brown slates are made, and also slates surfaced with crushed natural slate.

Straight Cover Slates.—These are rectangular slates made in three sizes: 24 × 12 inches, 20 × 10 inches, and $15\frac{3}{4} \times 7\frac{7}{8}$ inches. They are made in two patterns: square corners and chamfered corners.

Diagonal Cover Slates.—There are two patterns: a square drop or "diamond" point, and a chamfered lower corner giving a "honeycomb" effect. The size is $15\frac{3}{4} \times 15\frac{3}{4}$ inches.

COVERING CAPACITY: STRAIGHT COVER SLATES

Size of Slate.	24 × 12 inches.		[illegible] × 10 inches.		$15\frac{3}{4} \times 7\frac{7}{8}$ inches.
Lap	3 inches	4 inches	3 inches	4 inches	3 inches
No. of slates per square (100 sq. ft.) .	114	120	170	180	289
Centres of battens	$10\frac{1}{2}$ inches	10 inches	$8\frac{1}{2}$ inches	8 inches	$6\frac{3}{8}$ inches

Add 5 per cent. for cutting and waste.

COVERING CAPACITY: DIAGONAL COVER PLATES

Size of Slate.	Method of Lap Laying.	No. of Slates per Square.	Centres of Battens.
$15\frac{3}{4} \times 15\frac{3}{4}$ inches	Honeycomb $2\frac{3}{4}$ inches	86	$8\frac{1}{8}$ inches
$15\frac{3}{4} \times 15\frac{3}{4}$,,	Honeycomb $3\frac{1}{2}$,,	99	$7\frac{3}{8}$,,
$15\frac{3}{4} \times 15\frac{3}{4}$,,	Diamond $2\frac{3}{4}$ inches	86	$8\frac{7}{8}$,,
$15\frac{3}{4} \times 15\frac{3}{4}$,,	Diamond 3 ,,	89	$8\frac{1}{2}$,,
$15\frac{3}{4} \times 15\frac{3}{4}$,,	Diamond $3\frac{1}{2}$,,	96	$8\frac{1}{4}$,,
$15\frac{3}{4} \times 15\frac{3}{4}$,,	Diamond 4 ,,	105	$7\frac{5}{8}$,,

Add 5 per cent. for cutting and waste.

Fixing Asbestos Slates.—The plates may be fixed either to close boarding or battens. Rafters may be spaced up to 30 inches centre to centre without extra thickness of battens or boards. This is a considerable economy on the usual spacing of 15 inches with clay tiles and natural slates.

If boards are used the batten gauge should be lined out with a slater's line so that the slates are laid to true parallel lines and uniform lap.

Asbestos-cement slates are fixed with two $1\frac{1}{4}$-inch galvanised nails 11 B.W.G., and the lower edge is secured from lifting with a copper disc rivet.

Underfelt is recommended in an exposed position or if the pitch is less than 26 degrees. This will prevent infiltration of rain, dust, and draught.

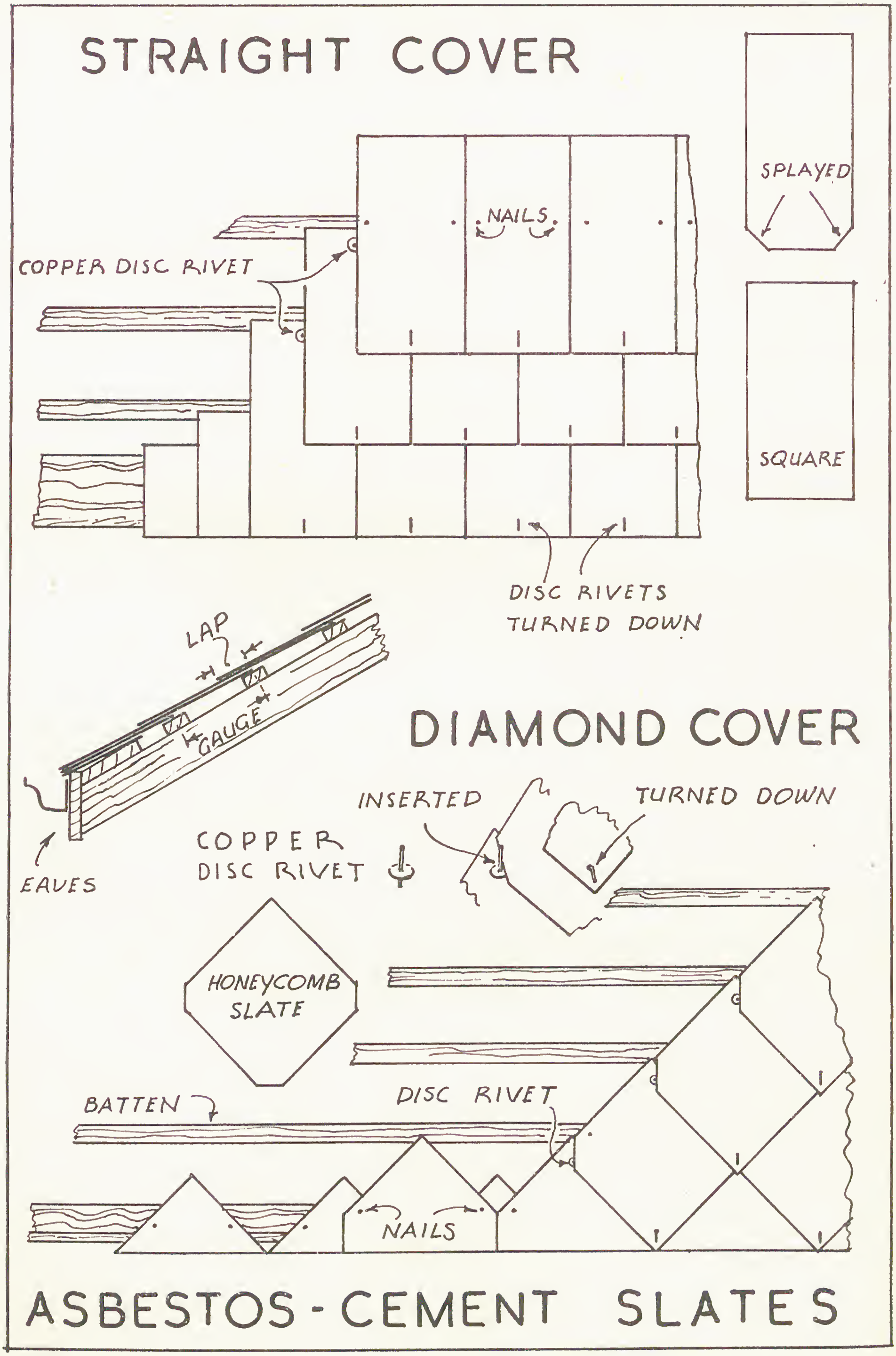

STRAIGHT COVER
SPLAYED
NAILS
COPPER DISC RIVET
SQUARE
DISC RIVETS TURNED DOWN
LAP
GAUGE
DIAMOND COVER
INSERTED
TURNED DOWN
COPPER DISC RIVET
EAVES
HONEYCOMB SLATE
BATTEN
DISC RIVET
NAILS
ASBESTOS-CEMENT SLATES

Fig. 230.

SLATING DATA

Purchases.—Slates are sold by the thousand (1,000 = 1,200), except in Westmorland, where they are usually sold by the ton, owing to their being Randoms.

Covering Capacity of Slates

Names.	Sizes.	Covering Capacity per 1,200 Slates at 3-inch Lap.		
		Squares.	Square yards.	Actual No. of slates per square.
Empresses	26 × 16	15⅓	170	78
Princesses	24 × 14	12¼	136	98
Duchesses	24 × 12	10½	116	115
Small Duchesses	22 × 12	9½	106	126
Marchionesses	22 × 11	8¾	97	138
—	20 × 12	8½	95	141
Countesses	20 × 10	7	79	169
—	20 × 9	6⅓	71	188
—	18 × 12	7½	83	160
Wide Viscountesses	18 × 10	6¼	69	192
Viscountesses	18 × 9	5¾	62	213
—	16 × 12	6½	72	185
Wide Ladies	16 × 10	5½	60	221
Broad Ladies	16 × 9	5	54	246
Ladies	16 × 8	4½	48	277
—	14 × 14	6½	74	180
Wide Headers	14 × 12	5½	61	218
Headers	14 × 10	4½	51	262
Small Ladies	14 × 8	3¾	41	327
Narrow Ladies	14 × 7	3¼	36	374
—	14 × 6	2¾	30	436
Small Headers	13 × 10	4⅛	46	288
Long Doubles	13 × 7	3	32	411
—	12 × 12	4⅔	52	257
Doubles	12 × 10	3¾	42	320
Wide Doubles	12 × 8	3	33	400
Small Doubles	12 × 6	2¼	25	533
Square Singles	10 × 10	3	32	411
Singles	10 × 8	2¼	26	514
Units	10 × 6	2	20	686

The traditional names, though given above, are now rarely used except by a few old quarrymen.

Nails must be specified by the weight per 1,000. The following are the weights of copper nails per 1,000 ·

Inches	Pounds
1	= 3¼
1½	= 9½
2	= 11¼
2½	= 29¼

Zinc Nails

Of $1\frac{1}{4}$-inch nails 290 go to the pound.
Of $1\frac{1}{2}$-inch nails 220 go to the pound.
Of $1\frac{3}{4}$-inch nails 140 go to the pound.
Of 2-inch nails 90 go to the pound.

Zinc Nails are used in cheaper-class work, but the heads are liable to break off, and are not very reliable in consequence.

Weight of Slate Slab per Foot Super in Pounds.

$\frac{1}{2}$-inch	$\frac{3}{4}$-inch	1-inch	$1\frac{1}{4}$-inch	$1\frac{1}{2}$-inch	2-inch
$7\frac{1}{2}$ pounds	$11\frac{1}{4}$ pounds	15 pounds	$18\frac{3}{4}$ pounds	$22\frac{1}{2}$ pounds	30 pounds

Lap.—For pitches of less than 30°, slates 12 inches wide should be used, and for very steep pitches, as on church spires, flèches, etc., a 2-inch lap only should be given.

POINTS IN SUPERVISION

A Good Slate when cut should show no signs of being crumbly at the edges; at the same time, it should not be too brittle, and it should be free from splinters.

Slates are properly laid when the rougher side is exposed to the weather, and the grain of the slate should run in the direction of the length of the slate.

Welsh Slates may be distinguished from the Westmorland by being thinner, smaller, and finer.

Eaves.—Measure the eaves projection to see that this has been given, as specified, not less than $1\frac{1}{2}$ inches and note if all slates are laid to break joint.

Machine-punched Slates.—These are to be preferred wherever they can be obtained, as they are neater and the holes more cleanly punched.

STONE SLATING

Stone in comparatively thin slabs is used for covering roofs in certain districts, such as Gloucestershire, where a suitable stone is found. The chief requirement in such stone is that it should split readily into slabs which, though not so thin as slates, are of such a thickness that they can be used on roofs without rendering necessary roof timbers of such excessive dimensions as to be prohibitive.

Stone suitable for slating roofs is found as well as in the Cotswolds; in Sussex, the Horsham stone; in Oxford, the Stonefield slates; and in Dorset, the Purbeck stone. The Cotswold and Dorset stone slating is used in much heavier slabs than that from the other districts, and in consequence, the roof timbers have to be increased in size. Possibly it is partly due to this and to the fact that the Stone Slaters' Union is a very close corporation and that apprentices are not taken on readily, that even in stone districts materials such as slate and clay tiles are fast superseding the use of the material to be found locally. This is a great pity, as always the most suitable material to be used in any district is that which is a natural product of the district, for beyond looking most suitable, it is actually so in point of durability. Such an action on the part of the stonemasons is to be much regretted, and even though it may be permissible to keep trade secrets to be shared in only by those admitted to that trade, yet it is an inexcusable folly to monopolise anything to the extent of killing it.

No doubt from some such idea a certain mystery is wrapped round the stone slater's operations, to the extent that the slater only can size the stones required for a job, because this sizing is done with a rule which only he or one of his fraternity can understand. This rule is a square batten about 2 feet 6 inches long, having near one end a hole bored through, and along the upper face certain signs, which resemble Roman figures but are not. Herein lies the secret. However, as a peg is put through the hole in the rule and into the hole in the stone slate, and the name of the slate is determined by the mark on the rule to which the slate extends, it only remains to measure the stones by such a rule in conjunction with a 2-foot rule to discover the mystery—at least, so far as the names and sizes of the slates are concerned.

The following is a list of the names of stone slates, and their lengths are given by Mr. Nathaniel Lloyd in *Building Craftsmanship*, as obtaining in the Witney-Oxon district:

Long sixteens	23 inches long	Short Wivelly or Wippetts	13½ inches long
Short sixteens	22¼ inches long	Long nines	12½ inches long
Long fifteens	21½ inches long	Short nines	11¾ inches long
Short fifteens	20¾ inches long	Long bachelors	11 inches long
Long fourteens	20 inches long	Short bachelors	10½ inches long
Short fourteens	19¼ inches long	Long becks or hops	9¾ inches long
Long thirteens	18½ inches long	Middle becks	9¼ inches long
Short thirteens	17¾ inches long	Short becks	8½ inches long
Long twelves	17 inches long	Muffity or Moredays	8 inches long
Short twelves	16¼ inches long	Long cuttings	7½ inches long
Long elevens	15½ inches long	Short cuttings	6¾ inches long
Short elevens	14¾ inches long	Thirds	6 inches long
Long Wivelly or Wippetts	14 inches long	Cocks or Tants	5¼ inches long

The stone slates are fixed to battens either by an oak peg at the centre of the head or by two brass screws, which are better than a peg in exposed situations, or lastly, by a galvanised-iron nail, to either single or double battening. The double battening laid over boarding ensures ventilation under the slating, and is preferable, but, of course, slightly more costly. The courses in stone slating are diminished from the eaves upwards, the course above the eaves course being termed the "follower." The ridge is sawn from a block of stone, and has two wings in one piece, or in cheaper work the stone ridge is omitted, the space between the two top courses being filled with cement, which is also spread downwards over the top course of stone slating.

Under the eaves an under-eaves course is formed of stone termed "cussomes," bedded in mortar, and hooked under the first batten to give

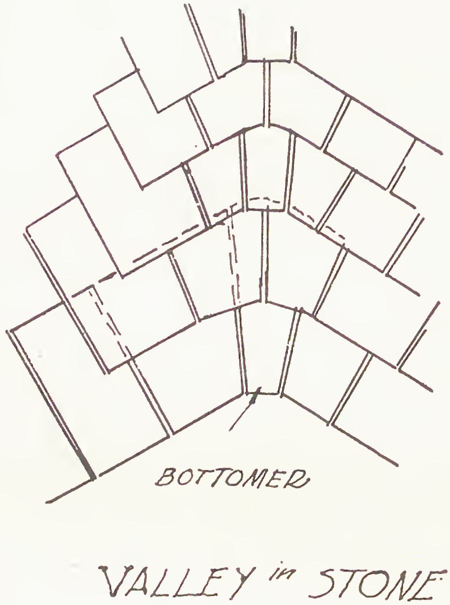


Fig. 231.—Details of stone roofing

it an anchorage—a shorter stone is used for this course, as its bottom end terminates equally with that of the eaves course.

Valleys are swept round in the manner described in Chapter 12 on Tiles and Tiling, with specially trimmed wedge-shaped slates. Or, alternatively, as this is skilled work, the valleys are formed in lead with cement filling under.

Hips are naturally avoided, as the material does not lend itself to the formation of satisfactory hip tiles. Where, as in dormer windows, they do occur, in stone slates of smaller dimensions they are splay cut and mitred, the timber underneath being covered with 5-pound lead. Stone-roofed buildings, however, are generally designed with gable finishes to the roofs. Exposed verges are more soundly protected with coped walls, the coping being kept above the stone slates, and the space behind being filled in with cement mortar.

As the practice of laying stone slating, where it is still continued, varies so much with the district, and as has been stated, the trade is in the nature of a monopoly, it is almost a foregone conclusion that local workmen will have to be employed and the workmanship resulting will be that obtaining in the district.

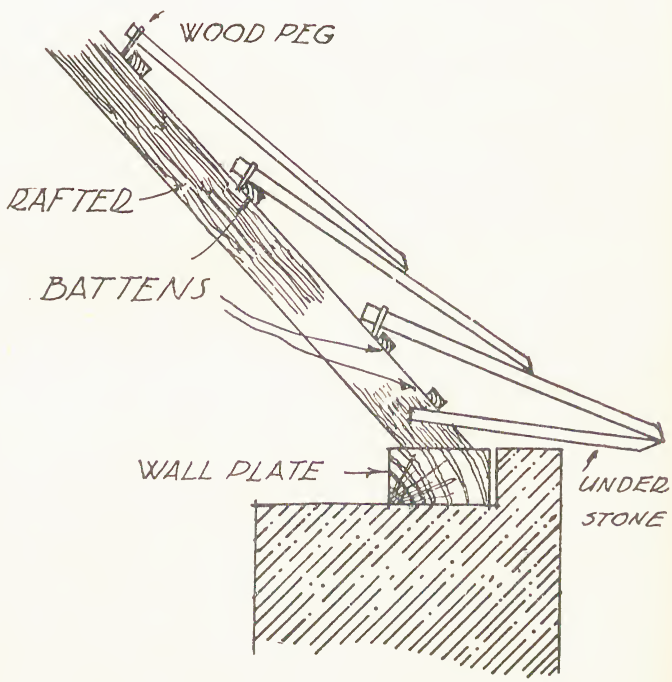


Fig. 232.—Details of stone roofing.

The Delabole Slate quarried in Cornwall is sometimes specified as stone slating, and though this certainly resembles stone, yet it is in fact a slate.

CHAPTER 14

THATCH AND SHINGLES

THATCHING is not suitable for modern buildings in towns and urban areas, but it still has a legitimate place in rural districts, at least where suitable wheat and rye straws or reeds, and skilled craftsmen, are available. Fire risk is often mentioned as an objection against thatch, but the following chemical treatment will greatly reduce this, though it is necessary to renew it about every three years: Mix a solution of $\frac{3}{4}$ lb. alum, $\frac{3}{4}$ lb. copper sulphate, and 50 galls. water. Soak the straw or reeds in this for 48 hours, weighting down the material to keep it immersed.

Another objection to the use of thatch is that the birds make large holes in it, but if the thatching has been properly performed they will have great difficulty in so doing, certainly during the early years of the life of the thatch; and as an additional preventive measure, the entire roof may be covered with wire netting of sufficiently small mesh to keep the birds out, and this will be hardly noticeable after the first few months. Also it would be advisable to arrange beforehand for a supply of straw cut in the old way and without being passed through a threshing machine. Such a roof, sprayed with preservative, will scarcely require any additional attention for fifteen years, which is a quite reasonable durability.

The best thatch is composed of "reed straw," but this is difficult to obtain except in the Fen districts in Lincolnshire. Good long wheat straw will serve to form very satisfactory and weatherproof roofing, which has the additional advantages of being light and forming a covering which is non-conductive of heat and cold.

The Process of Thatching is commenced by shaking out the straw into heaps on the ground, when it is watered until thoroughly wetted. Protruding ends are then caught hold of, and the straw is pulled out in handfuls and laid straightly side by side in bundles, which are termed "yealms." These yealms are made from 4 inches to 6 inches deep and about 10 inches wide, and they are then tied at the butt ends with tarred or creosoted twine. They are then ready for laying on the roof.

The laying of the straw should not be less than 25° on the roof, and the pitch of the roof should be something over 45°, even up to 60°, as the angle that the straw itself makes with the horizontal is considerably less than this. In Dorset the straw is laid on the roof loose and squeezed tightly together and fastened down by rods and tied with "ropeyyarn," which is the trade name for tarred twine; the bottom, or eaves course, which is the first laid, is fastened with a rod and iron crooks driven into the rafters.

The timbers of the roof may be as wide apart as 2 feet, and on 8-inch centres up the roof; and to these battens, or rods of ash or other saplings, are fixed, the bundles of thatch in turn being tied with the tarred twine to these.

Well-laid thatch is that which shows only about 4 inches of the sides of the straws above the stub end. In laying, in order to cause it to lie straight it is combed with a short-handled rake and trimmed off evenly with a thatching hook. At the bottoms of the rafters a wood tilting fillet of something over 3 inches projection is fixed, and over this an eaves board is nailed. The eaves of the thatch are continued past and below this board and cut square at right angles to the wall face.

In some districts the ridge is formed by bending over the last course laid and weighting it down with a mixture of equal parts of slaked lime and loam or clay. In other districts it is only tied down. The top ends of the "yealms" on the other slope are then bent over these and fastened down on the side first laid, and laced with hazel sticks and spiked into the straw under. When reeds are used, as in Norfolk, they are too stiff to bend over the ridge in this manner, so that rushes are used for the ridge finish.

Fireproofing may be conveyed to the straw by mixing the fireproof speciality with the water used to soak the straw before it is laid in; and a comparatively cheap precaution can be taken which should be favourably considered by the insurance companies. This is to lay along the ridge a perforated pipe which can be connected with the water supply in case of need; or to fit the pipe permanently connected with a stop-cock situated in some handy position *outside* the building, so that in the event of an outbreak of fire, the stop-cock may be immediately turned on, when a stream of water will run down each side of the roof. This will spread out over the thatch and so prevent a fire spreading to it from another source by flying sparks, as has so frequently happened in the past.

Verges are finished in the same manner as eaves, and the best finish for dormers is that termed the "eye brow." Valleys are rounded out after a lead gutter has been fixed in an angle in the usual manner.

Gutters.—Owing to the wide projection given to eaves, it is not actually necessary to fix an eaves gutter, and where fixed they are somewhat unwieldy-looking constructions. These generally consist of a V-shaped gutter formed by two boards nailed together at right angles and supported from the wall by wood or metal brackets. The down spouts may be of wood or metal, but the swan neck will have to be of an unusually wide sweep unless, as is more often seen, the gutter is connected to a sloping gutter at the gable end of the building.

WOOD SHINGLES

Shingles are thin strips of cleft wood 16 inches long and varying from $2\frac{1}{2}$ inches to 14 inches in width. Though more generally used in the U.S.A. and Canada, British Columbia red-wood cedar shingles are to be obtained from Messrs. W. H. Colt, Ltd., of London. These are of two classes :

Sawn Edge Grain.—This is a sawn shingle cut from logs of British Columbia red cedar in 16-inch lengths of random widths varying from 3 inches to 8 inches. The first quality is free from knots and sap, and as its name suggests, its grain runs along the edge of the shingle. This is a safeguard against curling and warping, as shingles cut with the grain are liable to warp, cup, and curl under extremes of temperature, causing splitting and consequent leakage in the roof.

The Saxon Shingle is a hand-split shingle longer and heavier, being obtainable in lengths up to 25 inches, and having greater durability than the sawn variety. Being split by hand it is more irregular in outline and texture, but can be obtained in specially dimensioned lots all 6 inches wide.

Oak.—Cleft oak shingles, mostly of narrow dimensions, are used on church spires. These vary in size from 12 inches to 27 inches in length and from 4 inches to 6 inches in width, and from $\frac{1}{16}$ inch to $\frac{1}{2}$ inch thick.

Cypress.—Shingles are also cut from cypress, which make the best shingles, having a rough sawn face. Cypress shingles are said to be more durable than redwood shingles, but the latter have a more pleasing appearance and are comparatively slower in burning.

Cedar Shingles are considerably cheaper than redwood and cypress, and if dipped in oil their durability is increased, though the old-fashioned split pine shingle left little to be desired in this matter of durability, there being roofs still in existence near Boston, Mass., U.S.A., which were erected over sixty years ago.

The fact that they are considerably cheaper than slates or tiles and that their use enables considerable saving to be effected in the roof timbers required, renders them particularly suitable for housing estates, on the roofs to out-buildings, in which they are already much used.

Laying.—The rafters, as has been suggested, may be fixed at distances as far apart as 2 feet for shingles, either on battens or close-boarded roofs. The thickness of the battens depends upon the distance apart of the rafters, and for distances of 2-foot centres $\frac{3}{4} \times 4$-inch battens are required.

Each shingle is nailed with two nails 8 inches from the butt and 1 inch from the side and to show $4\frac{1}{2}$ inches to the weather.

Nails.—Ordinary wire nails should not be used, but they should be zinc-coated, galvanised or copper, from 1 inch to $1\frac{1}{2}$ inches long. The quantity of nails required is approximately $2\frac{1}{2}$ pounds per square, and the nails should be given a covering of at least an inch by the shingle above.

A chalked line or straightedge is used in laying—the laying begins from the eaves course, which should be triple thickness. A simple method is to lay a batten to a gauge of $4\frac{1}{2}$ inches measured from the butt of the

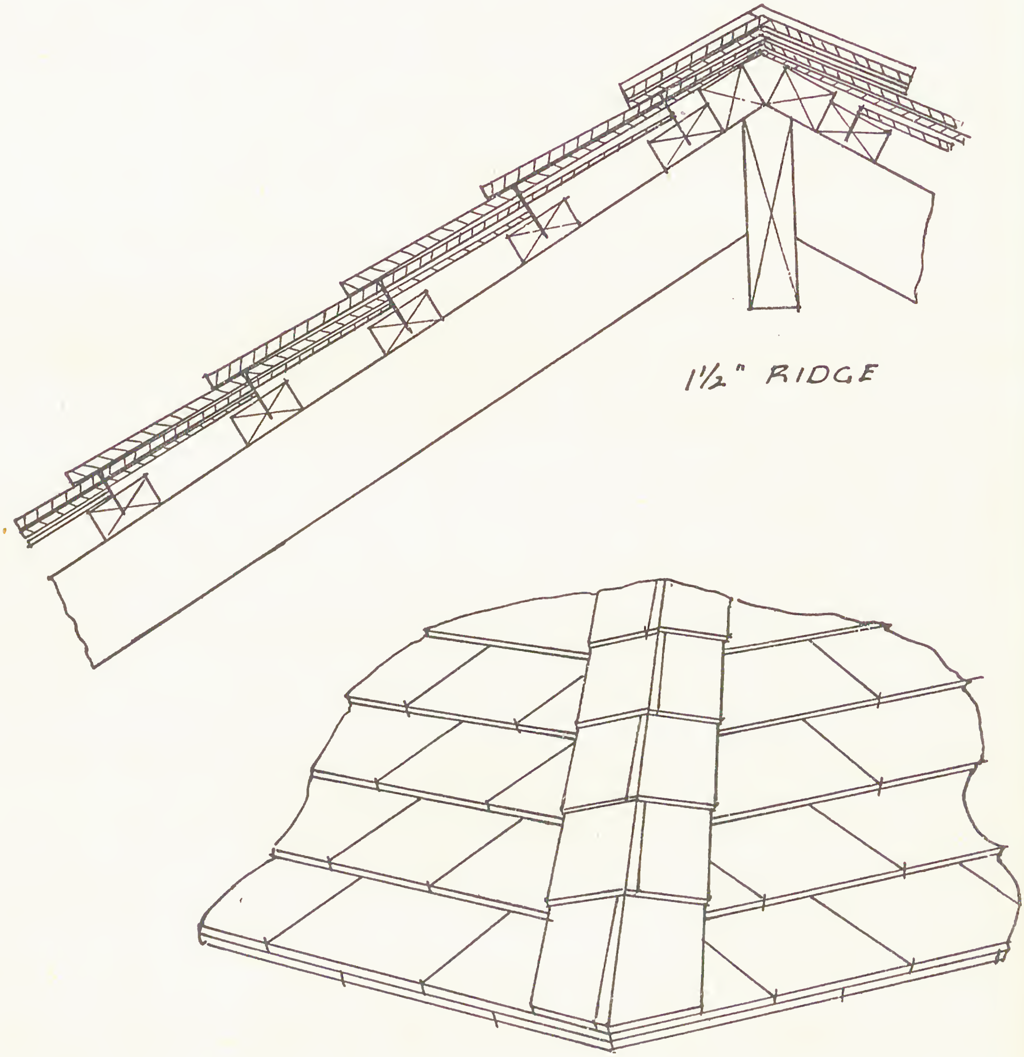


Fig. 233.—Shingles—detail of roof at 30° pitch with 16-inch shingles.

first or eaves course, and to place the butts of the second course touching this batten. The batten is removed when the course is laid and tacked in position $4\frac{1}{2}$ inches higher up for the subsequent courses or to any other gauge specified. As the widths of the shingles in the bundles are random, they are generally roughly sized and placed ready in bundles on the roof handy for use. Care should be taken to break all vertical joints in adjacent courses, and a break should be given to these joints of at least $1\frac{1}{2}$ inches. Side joints should not be butted tight, but laid with a $\frac{1}{8}$-inch gap, and any shingle over 10 inches in width is generally split down the centre.

Oak shingles are hung with two oak pins to each shingle, and in narrow width are the most suitable type of shingle for domed roofs as formed on turrets.

Ridges in Shingles are formed in a variety of ways, the cheapest method being to cover the angle joint with two $5 \times \frac{7}{8}$-inch boards nailed together at the angle required by the pitch of the two slopes. Before this ridge board is fixed the projecting ends of the shingles must be sawn off to a straight even line, and the ridging should preferably be screwed to the ridge board or to the rafters. Another method of forming a wood ridge is to fix a three-quarter round or a pear-shaped ridge roll with two wings on the apex after the shingles have been cut. Ridges are also formed of metal by fitting to the apex a wood ridge board of 3 inches in depth, having the top edge rounded, and over this and on to the shingles is laid a strip of lead or zinc screwed to the ridge roll and to the rafters at a distance of about 3 inches from the bottom of the metal strip. Galvanised-iron or copper rolls may also be used, turned over the ridge board, and screwed down on to the shingles.

Hips in Shingles are formed in a manner similar to that described for ridges, and in addition the parallel hip, as used in tiling, is also employed. Close shingling consists of cutting the shingles to the required angle to fit tightly, and flashing under in the usual manner with lead or zinc flashings. Over each pair of shingles a lead or zinc flashing, 5×5 inches, bent to the required angle, is nailed, so that it finishes just above the bottom of the next shingle. This will prevent the shingle from warping and from being stripped by the wind. The edges of the cut shingles should be lapped on alternate sides. On church spires this method is modified by the insertion of a $1\frac{1}{4}$-inch wood bead, which is nailed to the boarding on the line of the hip, and covered with long strips of sheet lead 10 inches wide turned over the roll and spread over the shingles, the edges of the shingles being lapped over the flashing and laid close against the $1\frac{1}{4}$-inch roll.

The third method of forming a hip is to lay a course of 5-inch shingles parallel with the hip line and lapped 1 inch at their top and lapping alternately at their edges.

Flashings.—If laid tightly fitting there is not the same danger of leakage at ridges and hips as at points where vertical faces intersect the shingle roofing, such as chimney stacks, parapet walls, skylight openings, and also in valleys which, being re-entrant angles, tend to collect the water more than the former.

For the purpose of rendering such joints watertight metal flashings of lead or zinc are used, with coverings known as counter flashings.

The Flashings for Valleys may be formed in either of two methods: a long strip of metal is laid along the hip, or small sheets cut to the required shape are interweaved between the shingles, so forming a continuous gutter of impervious material up the length of the re-entrant angle. The open valley formed of the long strip may alternatively be dressed over tilting fillets and nailed thereto, and the edges of the shingles laid over the tilting fillet. In roofs which are not boarded under the shingles valley boards must be run down each side of the valley rafter to take the lead.

Flashings against Vertical Brickwork.—On the faces where the brickwork joints are parallel with the roof flashings are formed: (1) on the high side, by dressing the lead into a gutter and finishing it under the shingles by tacking it to a tilting fillet. The lead in a single sheet must be 6 inches longer than the gutter or width of the chimney at each end to be dressed round the corner and over the side flashings. To cover the edge of the lead dressed up against the brickwork a cover flashing is let into a brickwork joint, lead wedged and pointed in cement, and turned down over the upright flashing. (2) The flashing on the lower face of the chimney stack is termed an *Apron Flashing*, and this also is 6 inches longer than the width of the chimney at each end. The apron is let into a brick course and wedged as before, dressed down the face of the brickwork, and over the top course of shingles at that point. At the ends the flashing is turned under a shingle.

Stepped Counter Flashings are used at the sides of the chimney cut in one piece to cover the small flashings interweaved between the shingles.

Kerbs to Skylights in shingle roofs are flashed in the following manner. Soakers are laid on the roof under the shingles and counter flashing is nailed up the side of the kerb and secured with a cover mould. In the case of a flat roof covered with lead, the edge of the lead on the flat surface is turned down over the top member of the cover moulding and tacked to this.

Points to be looked for in Superintendence.—Shingling is work which is very quickly done, and it is not an unusual experience to find that only one nail per shingle is being used, and as the nailed shingles are soon covered up there is no evidence of this until the job has been completed some time and the shingles begin to curl. When high winds arise the shingles will split down their length along the line of the nail hole.

Examine all gutters and lead work generally for nails; also see that the roof itself is swept before being painted or given the final coat of preservative. Inspect all flashings and counter flashings and make sure that a tight fit is left. All zinc shingles must be of the requisite size to fit the other shingles between which they are interweaved, and all counter flashings must be turned up vertical faces the requisite distance.

Vertical Shingling is hung to wall surfaces in a similar manner that the exteriors of walls are tile hung, and so hung they serve as a good protection against damp. They afford a far more pleasing appearance than walls hung with slates.

In hanging shingles to wall surfaces it is an additional precaution against damp penetration if the wall be first painted or treated with one of the damp-proofing preparations. The backs of the shingles should also be treated with a similar preparation or given a coating of creosote. The wall should then be battened, the battens being fixed to a gauge of 7 inches to show a 7-inch exposed surface of shingle.

Shingles in Repair Work.—Another use for the shingle is in the repair of old houses the brickwork of which is much decayed; or if the surface has been plastered and the stucco is much discoloured and cracked, their condition will be much improved, not only in appearance, but also from a structural point of view, if they be hung with shingles in the manner described above.

Shingling Data.—*Quantities.*—On hip roofs or for a roof with four valleys 5 per cent. should be added for cutting. On irregular roofs much cut about or with dormer windows 10 per cent. should be added for cutting.

Redwood shingles are reputed to go farther than cedar shingles.

With roofs under 45° pitch, cedar shingles should be laid with 4–4½-inch gauge.

For a pitch of 45° the gauge should be from 4¼ inches to 4⅜ inches.

On pitches above this angle they may be laid from 4½ inches to 5 inches.

Redwood shingles may be laid ½ inch more to the weather.

For vertical walling shingles may be laid 5 inches to the weather when they are cedar, and 6 inches when in redwood.

A bundle of shingles at a 7-inch exposure covers 45 square feet.

In America four bundles go to a thousand, a thousand in this sense being equivalent to one thousand shingles 4 inches wide.

The covering capacity of shingles is given in the following table:

No. of Shingles.	Gauge.	Area covered in square feet.
1,000	4¼	118
1,000	4½	125
1,000	4¾	131
1,000	5	138
1,000	5½	152
1,000	6	166

Labour.—In the U.S.A. the figures taken for estimating the labour are as follows:

A shingler should lay 1,500 shingles in 9 hours on plain work; and 1,000 shingles in 9 hours on cut and irregular roofs.

CHAPTER 15

ROOF AND WALL SHEETING

There are a number of waterproof and durable sheeting materials used for covering roofs and cladding framed walls. These are of three distinct kinds :

1. Asbestos cement.
2. Protected metal.
3. Corrugated steel.

They are made in several patterns, sizes, and thicknesses. The normal corrugated pattern is familiar, but there are other patterns which for some purposes are better.

ASBESTOS CEMENT

Asbestos cement is made from Portland cement and fibrous asbestos. The manufactured material is laminated but the layers are subjected to such great pressure that they are united into a homogeneous material. The material has now been long enough in use to prove its durability and adequate strength.

It is used for many purposes in building. For roofing, large sheets and tiles of various patterns are made, and also smaller slates which have already been described in Chapters 12 and 13.

The following are the chief sheets and large tiles :

Standard Corrugated Sheets.—These are made in three colours : natural grey, red, and russet-brown.

Standard lengths are from 3 feet to 10 feet, rising by 6-inch increments. The standard width is 2 feet 6 inches for all lengths.

With a side lap of approximately $4\frac{1}{2}$ inches ($1\frac{1}{2}$ corrugations) and an end lap of 6 inches, the net covering width when laid is 2 feet $1\frac{1}{2}$ inches.

The thickness is $\frac{1}{4}$ inch, number of corrugations per sheet $10\frac{1}{2}$, depth of corrugations 1 inch overall, pitch of corrugations $2\frac{7}{8}$ inches.

For roofing, the purlins should be spaced at 3-feet centres.

For side and gable cladding, the spacing of rails should not exceed 5-foot centres.

The weight per square (100 square feet) of laid sheeting is approximately $308\frac{1}{2}$ pounds, which is very much less than that of clay tiles or natural slates.

Curved sheets with standard corrugations are made to any radius down to 3 feet 3 inches. Turned-up sheets and a number of special flashing sheets are made for use with the standard sheets.

Large Corrugated Sheets.—Two well-known examples are termed "Big-Six" and "Super-Six." The corrugations are larger and deeper than with the standard sheets and consequently the sheets are stronger and purlins and rails can be spaced farther apart.

Standard lengths are from 3 feet to 10 feet, rising by 6-inch increments. The standard width is $41\frac{1}{2}$ inches for all lengths.

With a side lap of 2 inches (half a corrugation) and a horizontal lap of 6 inches the net covering width when laid is $39\frac{1}{2}$ inches.

The thickness is $\frac{1}{4}$ inch, number of corrugations per sheet $7\frac{1}{2}$, depth of corrugations $2\frac{1}{8}$ inches overall, pitch of corrugations $5\frac{3}{4}$ inches.

For roofing, the purlins can be spaced up to 4 feet 6 inches.

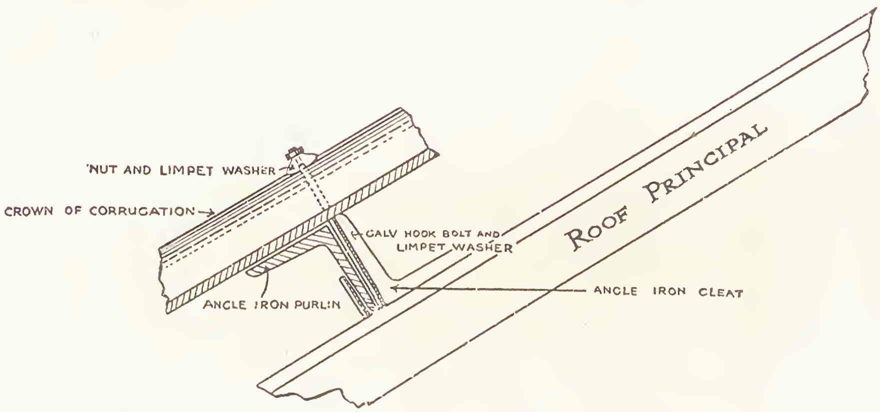


Fig. 234.—Method of fixing corrugated sheets

For side and gable cladding, the spacing of rails should not exceed 6 feet.

The weight per square (100 square feet) of laid sheeting is approximately 311 pounds. This is very little heavier than standard sheeting.

As with the standard corrugated sheeting, curved sheets are made (minimum radius 4 feet 6 inches), and a number of special fittings are made for flashings, etc., which enable a roof to be completed without using metal flashings.

Large Tiles.—The term "tile" in this connection may be misleading as it refers to sheets of asbestos cement as large as the usual sizes of corrugated sheet. These large tiles differ from corrugated sheets in having a flat between each two corrugations. The appearance is better than a corrugated surface, and whereas corrugated sheets are largely used on the roofs of industrial buildings, the large tiles are used on such buildings as cinemas.

Standard lengths range from 4 feet to 10 feet, rising by increments of 6 inches. The standard width of one make is 3 feet 8 inches and of

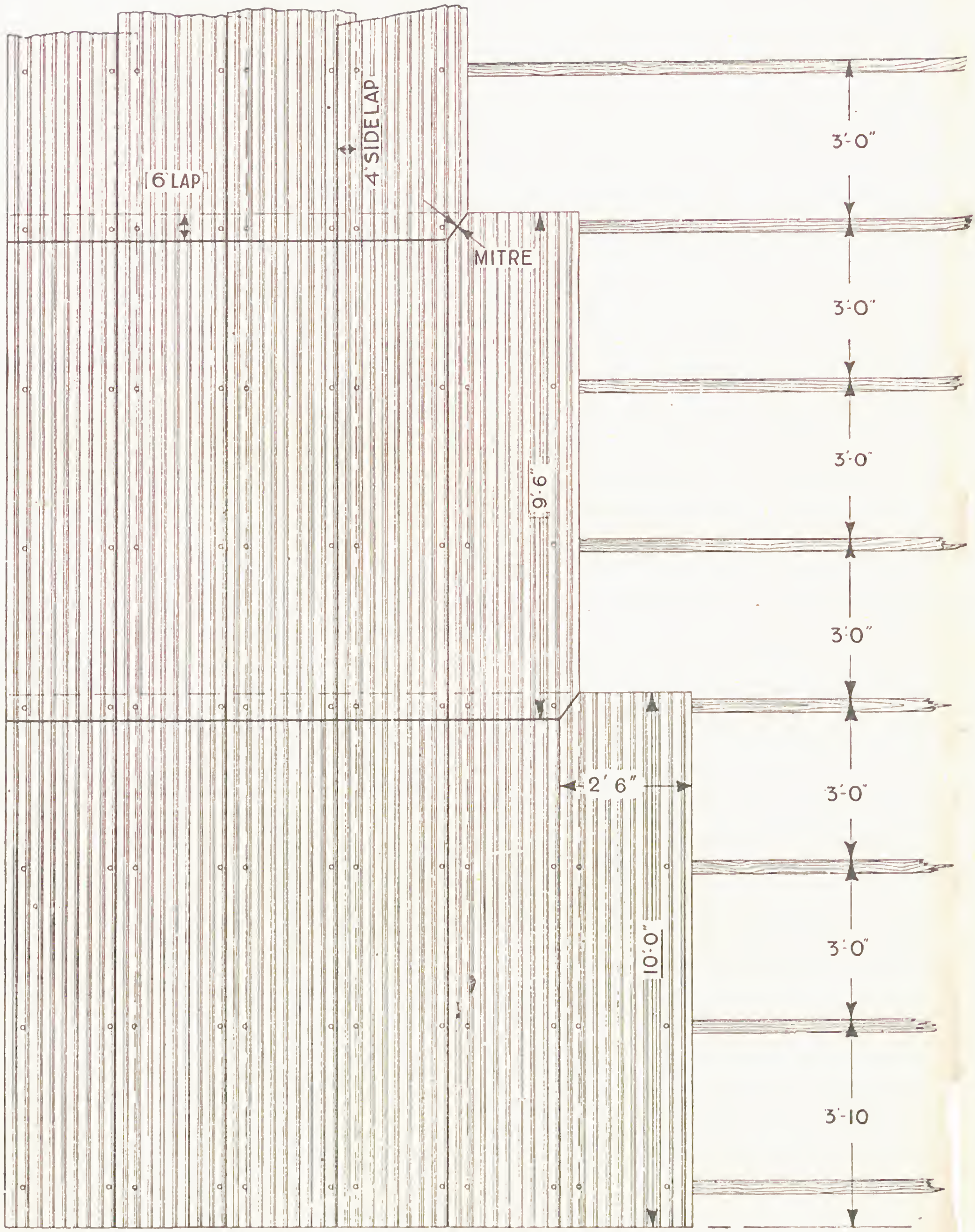


Fig. 235.—" Everite " asbestos sheets.

another 4 feet. The thickness is $\frac{1}{4}$ inch. The overall depth of the corrugation is 2 inches.

The weight of 100 square feet of laid roofing is approximately 304 pounds.

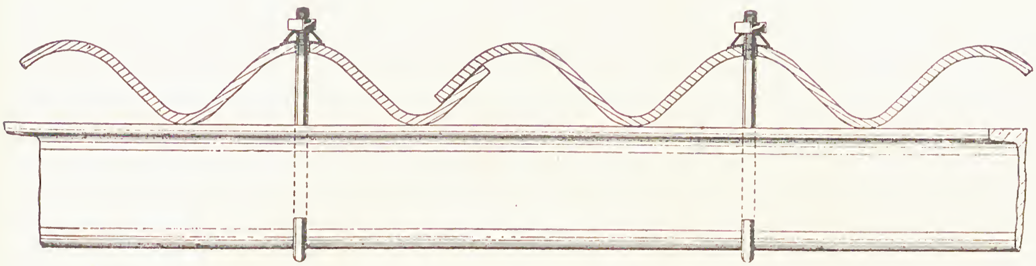


Fig. 236.—" Everite " asbestos sheeting. Section and angles.

Purlins may be spaced up to 4 feet 6 inches centres. Rails for vertical cladding may be spaced up to 6-feet centres.

Metal reinforced tiles are also available in 6-feet lengths for which the purlins are spaced at 5 feet 6 inches centres.

The side lap is 4 inches and the end lap 6 inches.

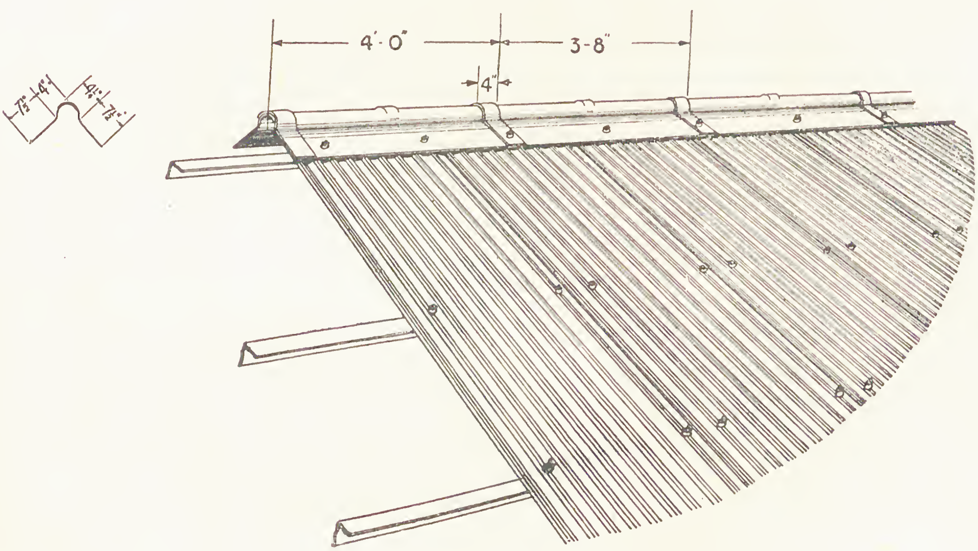


Fig. 237.—Asbestos ridging.

Fixing.—The holes for the screws and bolts are drilled, not punched, on the crown of the corrugations, and care must be taken to make the holes rather larger than the screws or bolts, and the holes must register one with the other exactly. The screwing down must be performed with care, as a too tight fixing will crack the corrugation at its crown. The sheets must be held by the screws firmly but not crushed.

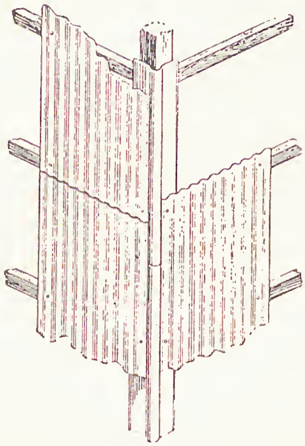


Fig. 238.—An asbestos corner.

The Use of Asbestos.—The extent of these uses and the variety of the industries served by asbestos products is surprising, including, as they do: mechanical engineering, electrical engineering, shipbuilding, the chemical industry, the motor industry, the building trade, and a variety of miscellaneous uses, such as the wipers used in the manufacture of metal wires and sheets, tying and looping and weaving of gas mantles, seating and packing for glass in glazing bars, lampwicks, parachute cords for Very lights, theatre safety curtains, boot socking and insoling, fireproof clothing, and railway-coach insulation.

Asbestos is a mineral that is fibrous in form, and herein lies its distinctive characteristic, which has made possible the many uses to which it is now put. It is this fibrous nature which enables this material to be used in the manufacture of so many products. Most other fibrous forms are associated with either the animal or the vegetable kingdom; the other exception being slag wood. Hair, wool, cotton, silk, hemp, and flax, for instance, are

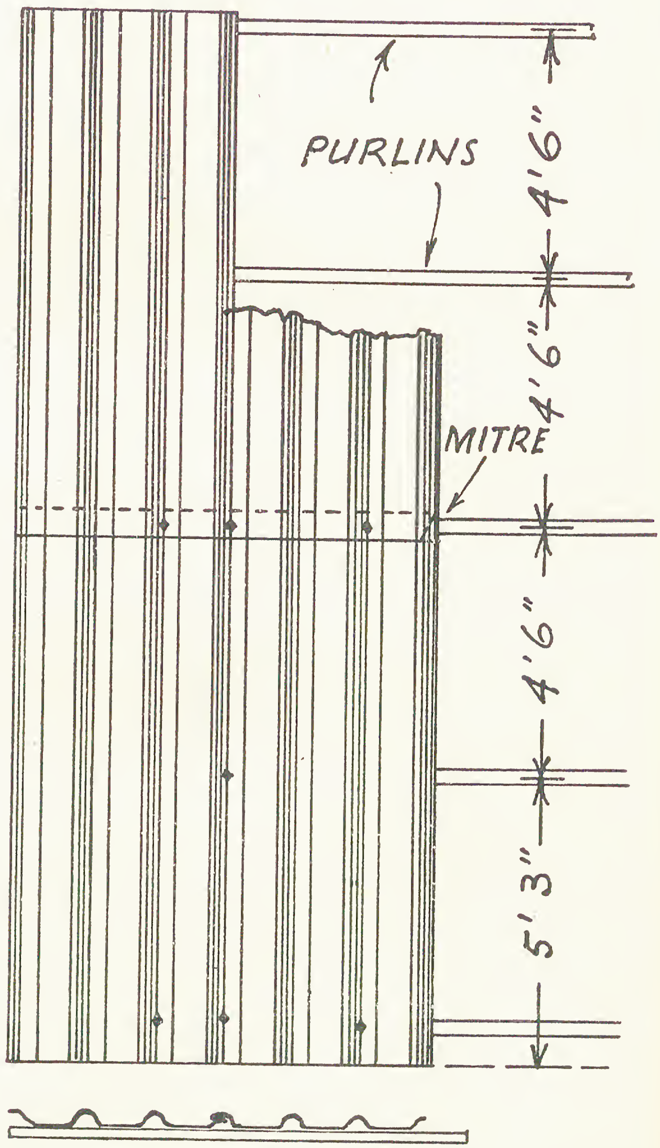


Fig. 239.—Asbestos-cement "Watford" tiles showing purlin spacing.

all derived from animals or plants, and burn very readily. Asbestos, on the other hand, though just as fibrous, being a mineral, will not burn.

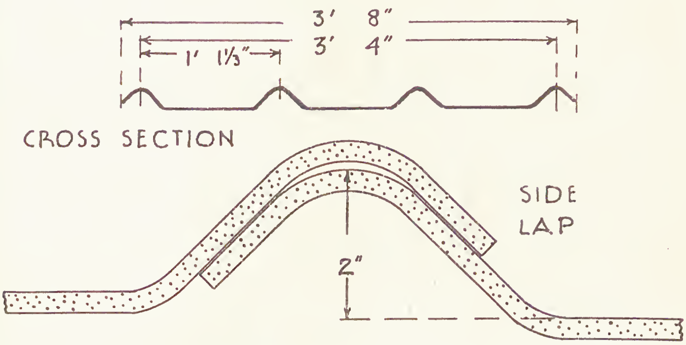


Fig. 240.—Asbestos-cement " Trafford " tiles.

Varieties.—Of the two varieties of asbestos in common use, one is white and the other blue: the common white fibre is called Chrysotile, and is a compound of magnesia, silica, and water. The blue fibre is constituted mainly of iron oxides, silica, and water. White fibre is softer than the blue, and lends itself to a much greater range of applications. Blue fibre is remarkable chiefly for its acid-resisting qualities.

The Formation of Asbestos.—Briefly put, the origin of asbestos formation is as follows: the first form of the rocks which gave rise to white asbestos was a molten lava consisting largely of a simple silicate of magnesia, containing no water, for water could not exist at the temperature at which volcanic or igneous rocks were ejected. This molten rock cooled, and then gradually became altered during the ages. Prolonged weathering caused the simple silicate of magnesia gradually to absorb and assimilate water, and become changed to serpentine. The serpentine in turn altered in form from an ordinary shapeless rock to a compact mass of microscopically fine, needle-like crystals, which go to build up asbestos. These compact clusterings of fine elongated crystals are the cause of the fibrous nature of asbestos.

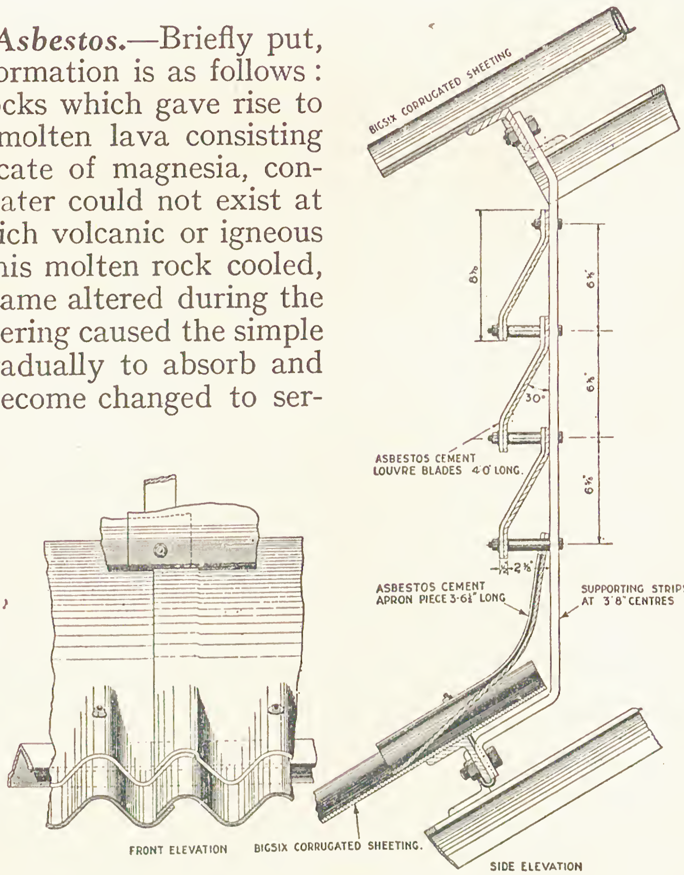


Fig. 241.—Asbestos louvres.

Asbestos is worked in mines in Canada, Rhodesia, the Transvaal, and Russia.

Asbestos Cement.—Asbestos cement is cement reinforced in a most effective manner by an intricate network of asbestos fibres. The asbestos is not there as an ornament, and is irreplaceable by any other fibre. It

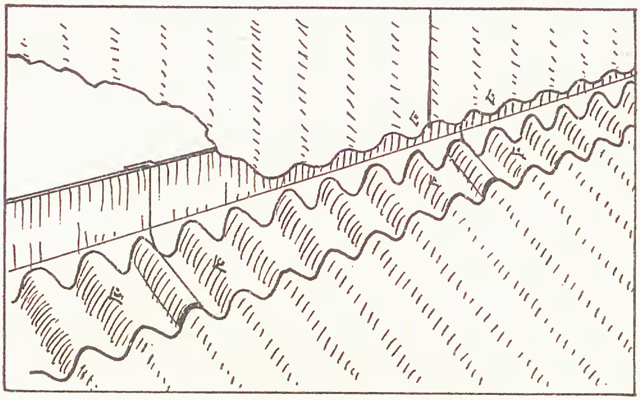


Fig. 242.—Asbestos-cement apron piece.

performs a double function. Firstly it enables the cement sheets to be handled, shaped, and moulded in the green and flexible state; and secondly, after the cement has set, it gives the necessary strength to allow them to be transported and fixed. The composition of asbestos cement may be taken as approximately 15 per cent. asbestos and 85

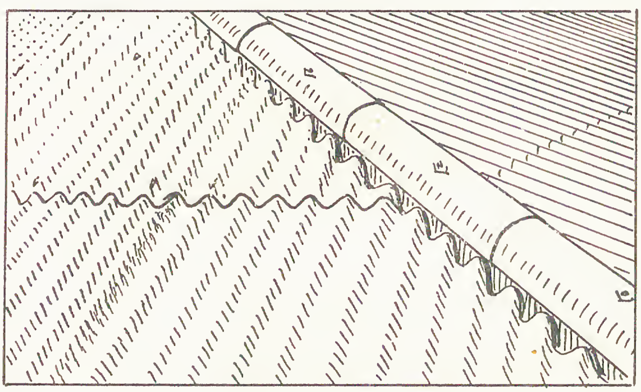


Fig. 243.—Asbestos-cement hip tile.

per cent. cement. It is an English-made product, and there is no adulteration.

The Manufacture.—The manufacture is simple in principle, but not too easy in practice. The fibre is mixed with cement in the presence of a great excess of water, and the whole is passed on to a fine sieve which allows the excess of water to escape, leaving a perfectly felted mass of asbestos and cement which is then pressed and put aside to mature. This is the simple outline. The aim of the manufacturer is to render such

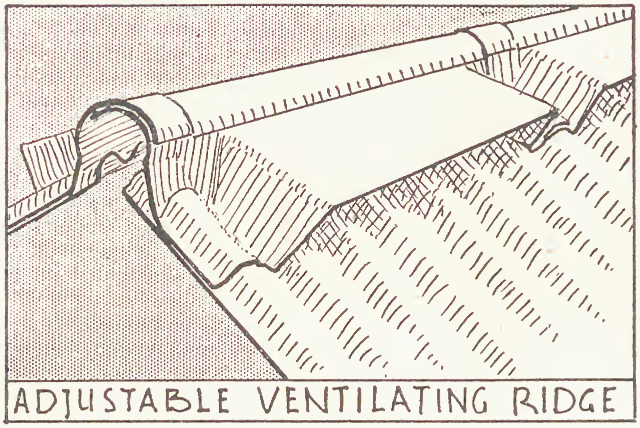


Fig. 244.—Asbestos-cement ventilating ridge fittings.

a process continuous, and to deal with the product quickly in order that it may be finally shaped or moulded before the initial set of the cement

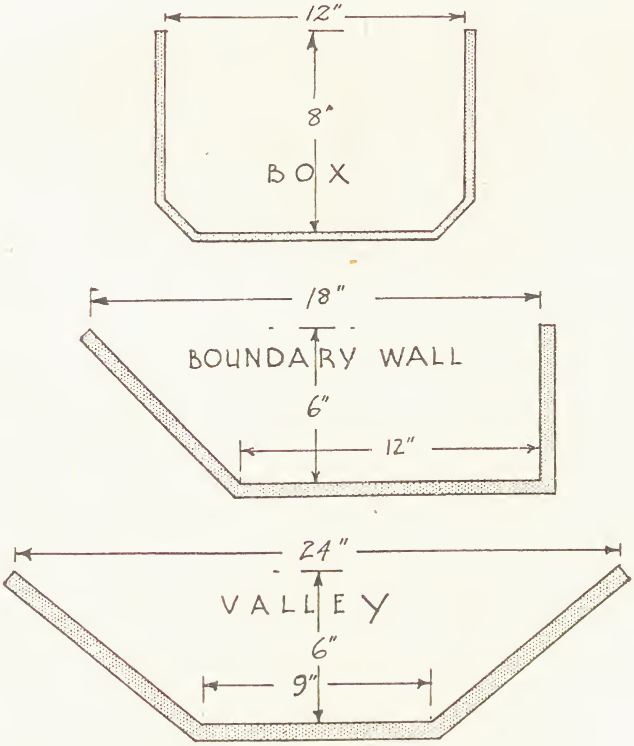


Fig. 245.—Asbestos-cement gutters for large roofs.

has taken place ; unfortunately, we may not give details of the interesting manner in which this is accomplished, but must content ourselves with noting that in the course of manufacture the sheets are subjected to great mechanical pressure. The complex machines employed in the process discharge a wet flexible sheet of unset cement and asbestos fibre which is then ready for conversion into flat building sheets, or for moulding into roofing tiles or slates. If it is required in sheet form it is cut to size, the edges are trimmed, and it is put away to mature. If required as a moulded roofing tile, it is passed through a corrugating or similar machine, trimmed and stacked. If required in slate form it is cut into sections according to

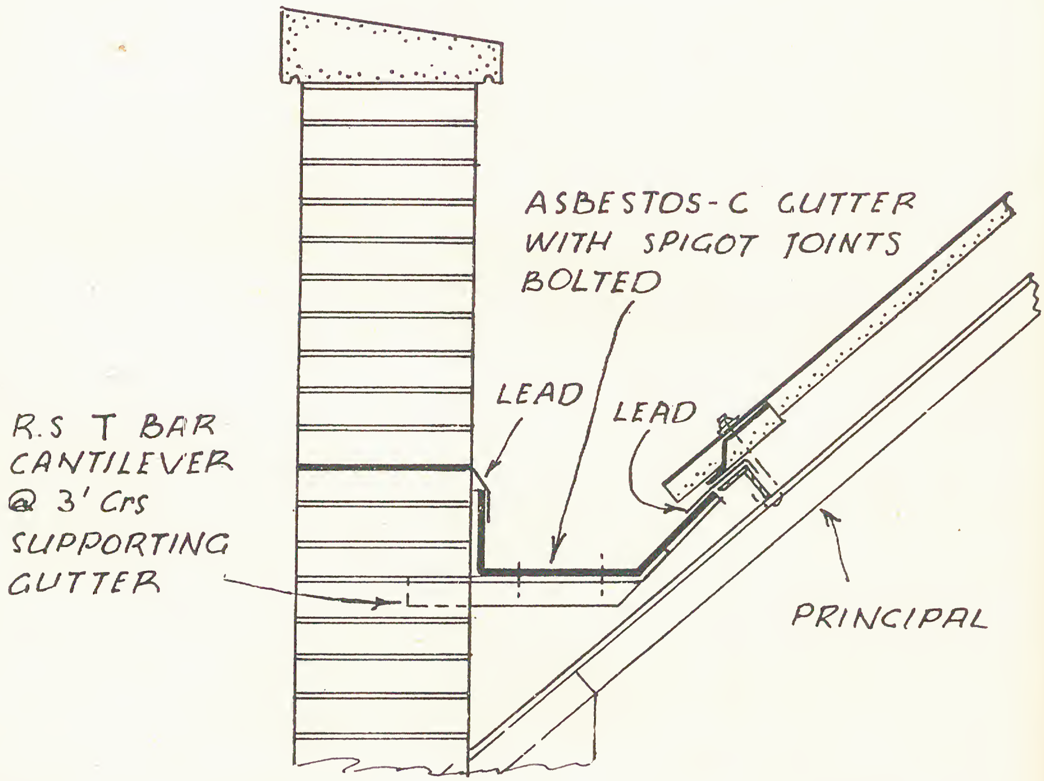


Fig. 246.—Asbestos-cement gutter behind parapet wall.

the desired pattern and subjected to further very high pressure in a powerful press.

Thus we have three principal types of asbestos cement:

(1) Plain sheets such as are used for walls.

(2) Large moulded roofing tiles in the form of corrugated sheets, Big Six, and Trafford Tiles.

(3) The smaller and more highly compressed slates.

PROTECTED METAL

Protected metal consists of steel-cored corrugated sheets, the core being entirely surrounded, including the edges, with a durable and weathertight sheathing of an asphaltic nature. This is strongly bonded to the steel so that the latter is completely and permanently sealed and cannot corrode.

Cellactite.—This make of protected sheeting consists of a compound of high-grade asbestos and asphalt consolidated by pressure with a steel

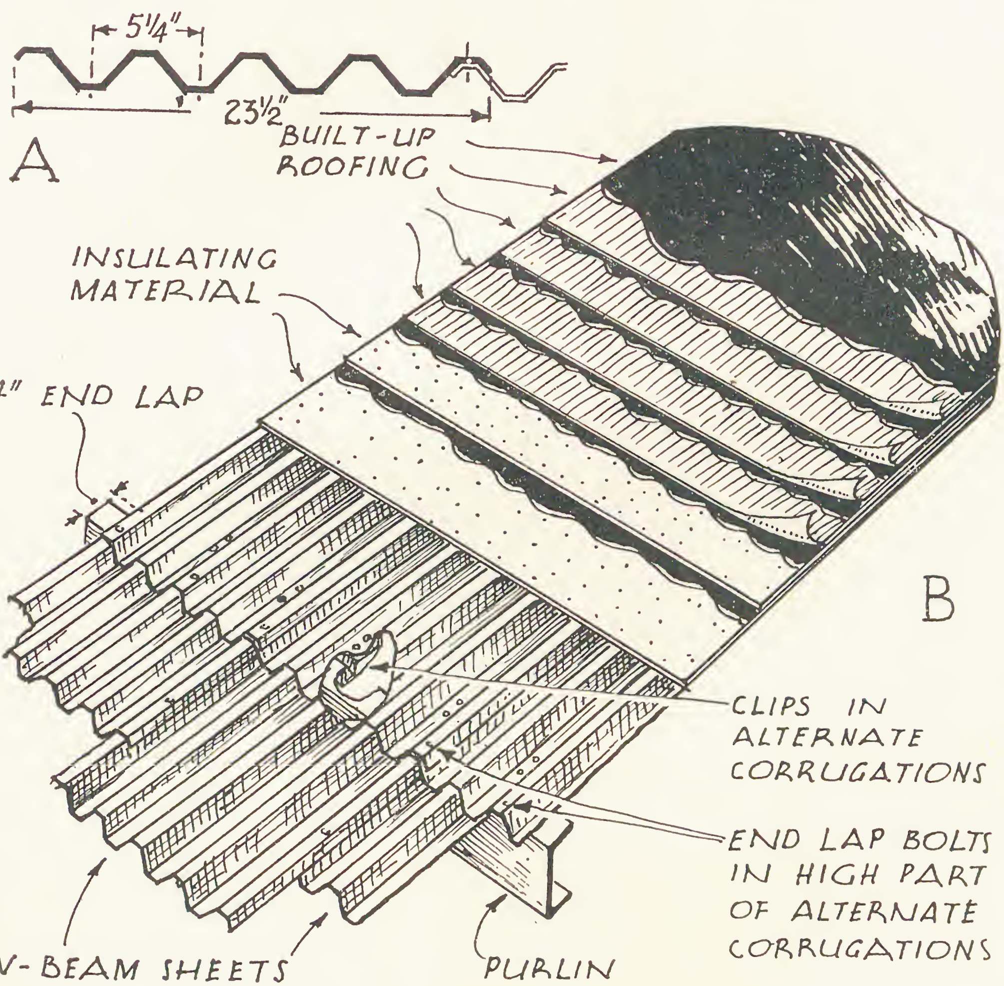


Fig. 247.—A, Section through V-beam protected metal sheet. B, Robertson V-beam roof decking.

core and finished in the form of standard corrugated sheets. It requires no painting or other protection and is permanent in an industrial or any other atmosphere.

The finished sheets have a hard glossy black surface, their substantial covering having high resistance to accidental abrasion. Coloured and special finishes are also available.

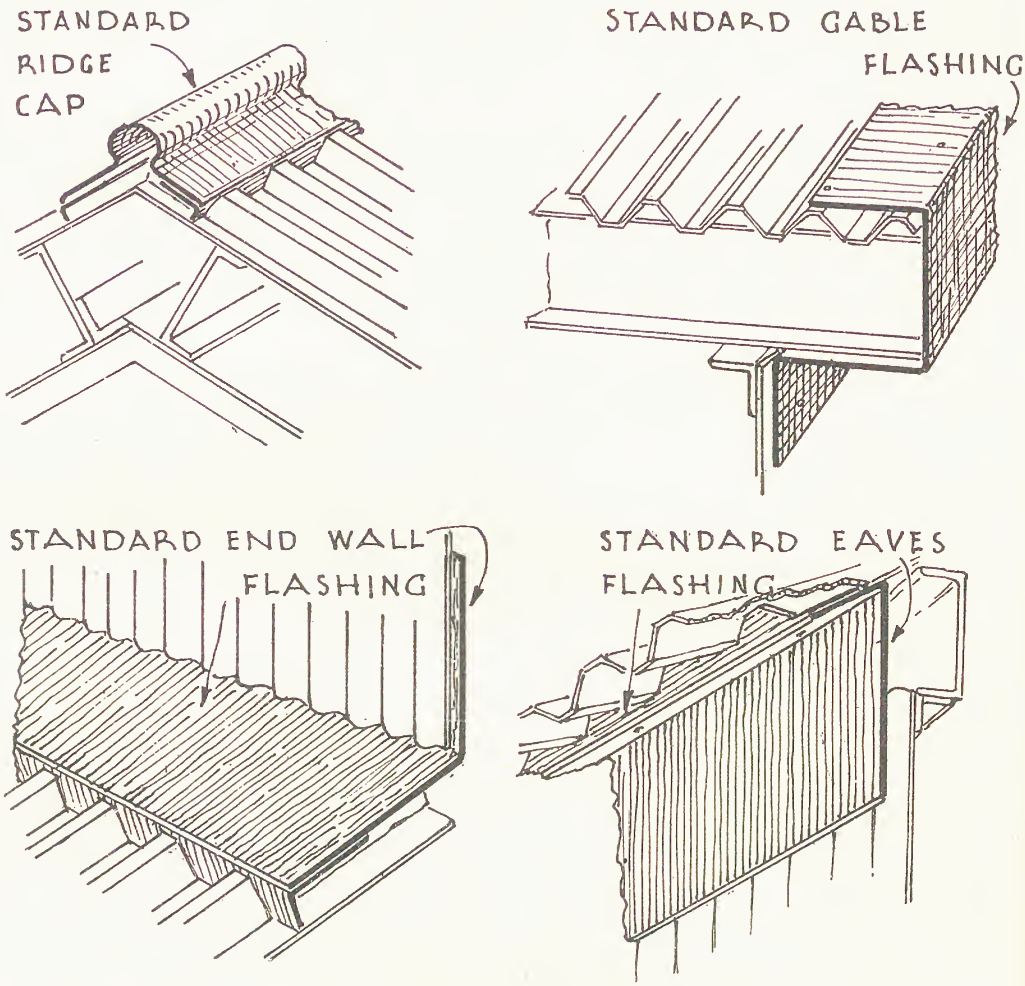


Fig. 248.—Fittings for Robertson V-beam roofing.

Cellactite is manufactured with steel cores of the following gauges:
Standard Cellactite, 28-gauge core.
No. 2 Cellactite, 24-gauge core.
Cellactite, 22-gauge core.
Cellactite, 20-gauge core.

The strength is increased by the strongly bonded protective covering.

Lengths up to 10 feet, rising by increments of 6 inches, are made, and the standard width is 2 feet 3 inches with nine 3-inch corrugations.

With a single corrugation side lap each sheet covers a width of 2 feet, and with a double corrugation side lap the cover is 1 foot 9 inches.

Curved sheets, flashings, ridges, and other special fittings are made in the same material.

Robertson V-beam Sheets.—These sheets are of V-shaped corrugated sections. The sheet-steel core is enclosed and hermetically sealed in

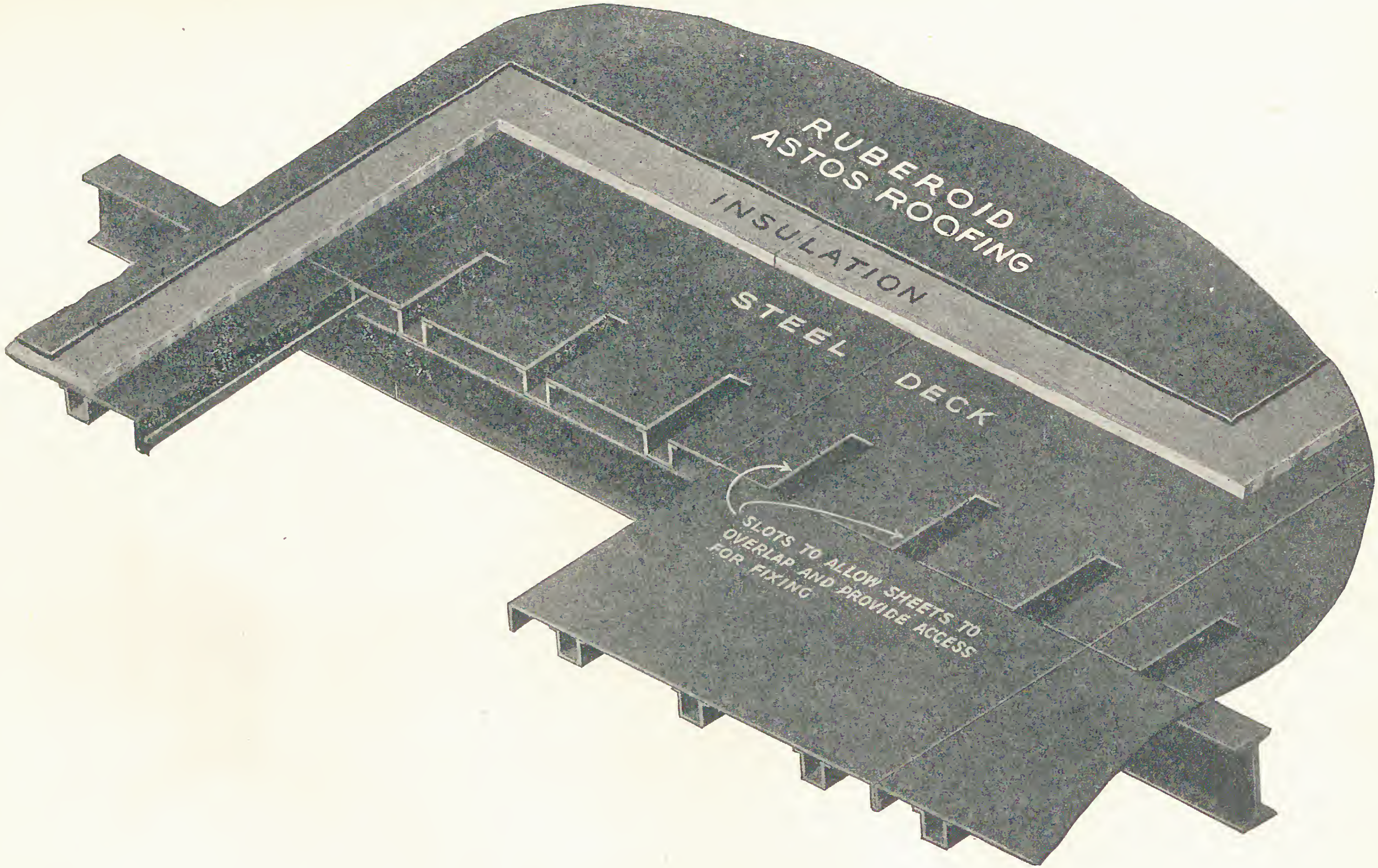


Fig 249.—Details of 3-channel Ruberoid Steel Deck cleated to R.S.J.'s with insulation and roof covering.
(By courtesy of the Ruberoid Co. Ltd.)

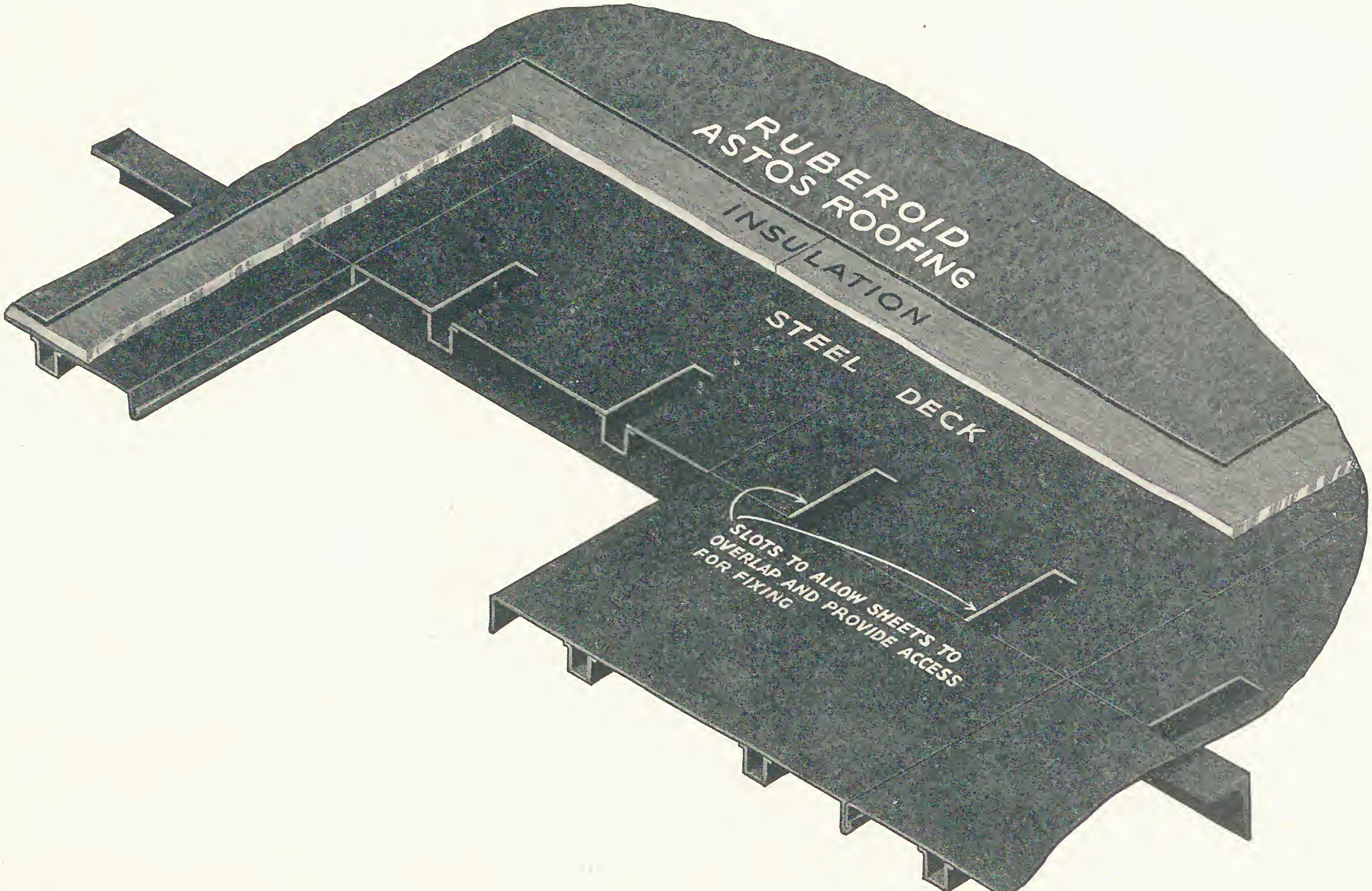


Fig. 250.—Details of 2-channel Ruberoid Steel Deck secured to steel angles with hook bolts, showing insulation and roof covering.
(By courtesy of the Ruberoid Co. Ltd.)

three protective coatings: 1, asphalt; 2, asphalt-impregnated asbestos felt; 3, a hard waterproofing envelope. This protective covering is proof against polluted industrial atmosphere.

The standard width is 23½ inches; net covering width 21 inches when lapped. Standard lengths 5 feet to 9 feet, rising in 6-inch increments, and 10 feet, 11 feet, and 12 feet.

There are three gauges of steel core: 24, 22, and 20.

Purlins may be spaced up to 8 feet for the 24 gauge, 9 feet for the 22 gauge, and 10 feet for the 20 gauge.

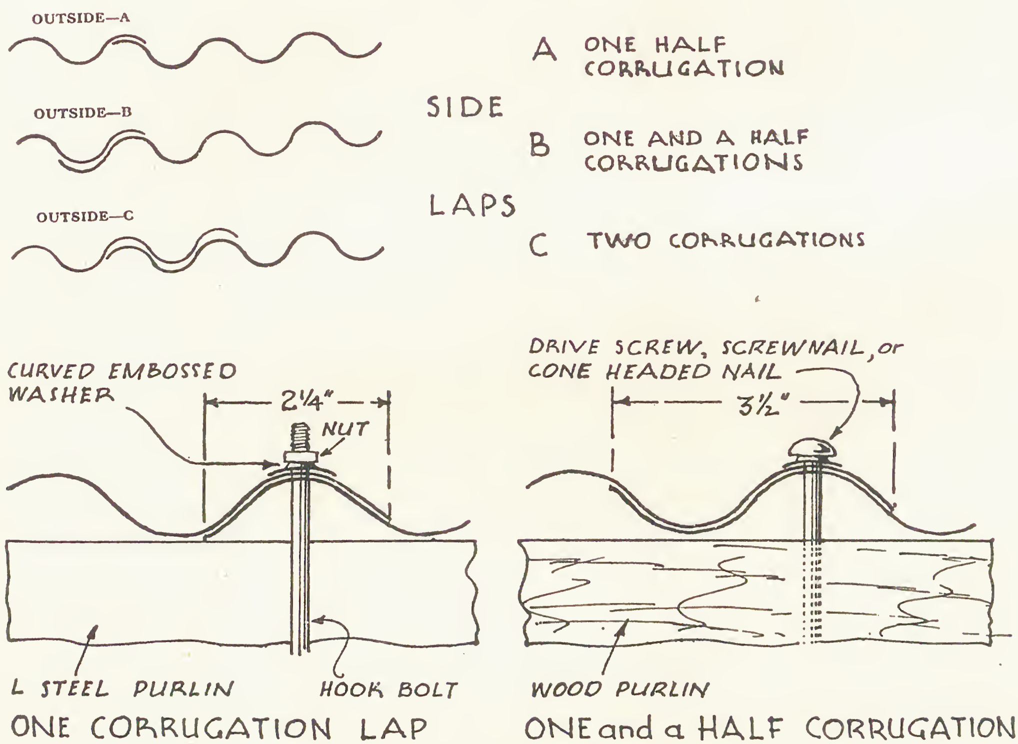


Fig. 251.—Corrugated iron—side laps and fixings.

The V-beam sheets may be used to form decking for flat roofs. Flat sheets of insulating material are fixed on top and asphaltic felt built-up roofing sealed to it with mastic.

Ridges and flashings are made of the same material.

CORRUGATED IRON

Sheet iron and steel, corrugated, is obtainable in a number of different sections, as illustrated in Fig. 252. It is obtainable galvanised or coated with bituminous paint.

It will be seen from Fig. 252 that in addition to the common corrugated

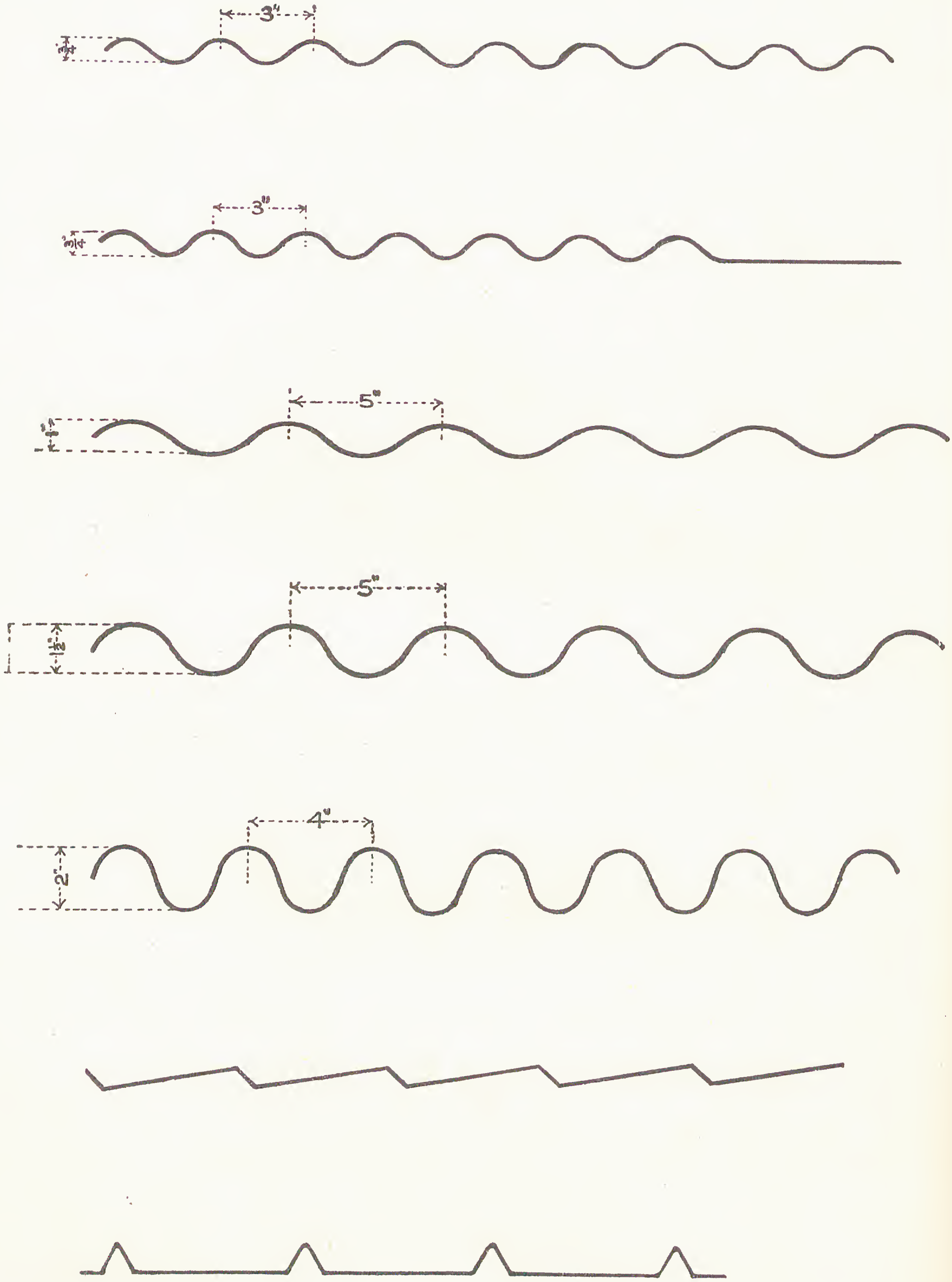


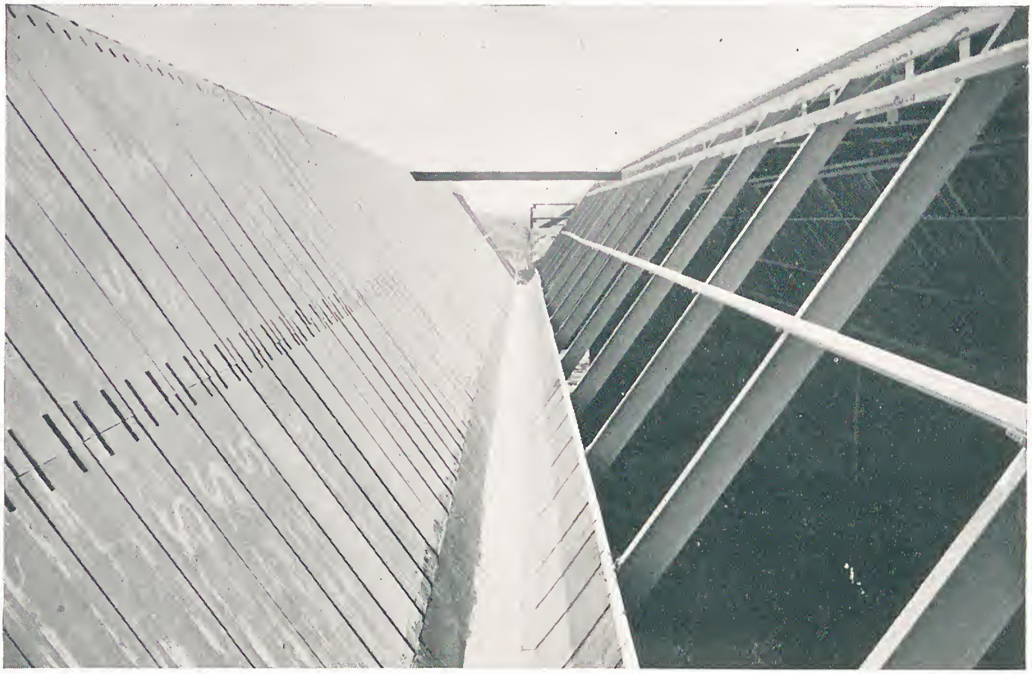
Fig. 252.—Corrugated-iron sheets—some typical sections.

INSTALLATION OF BRIGGS "BITUMETAL" ROOF AT BANBURY, SHOWING ½-IN. INSULATION BOARDS BEING LAID ON TOP OF ALUMINIUM DECKING BONDED WITH HOT BITUMEN.

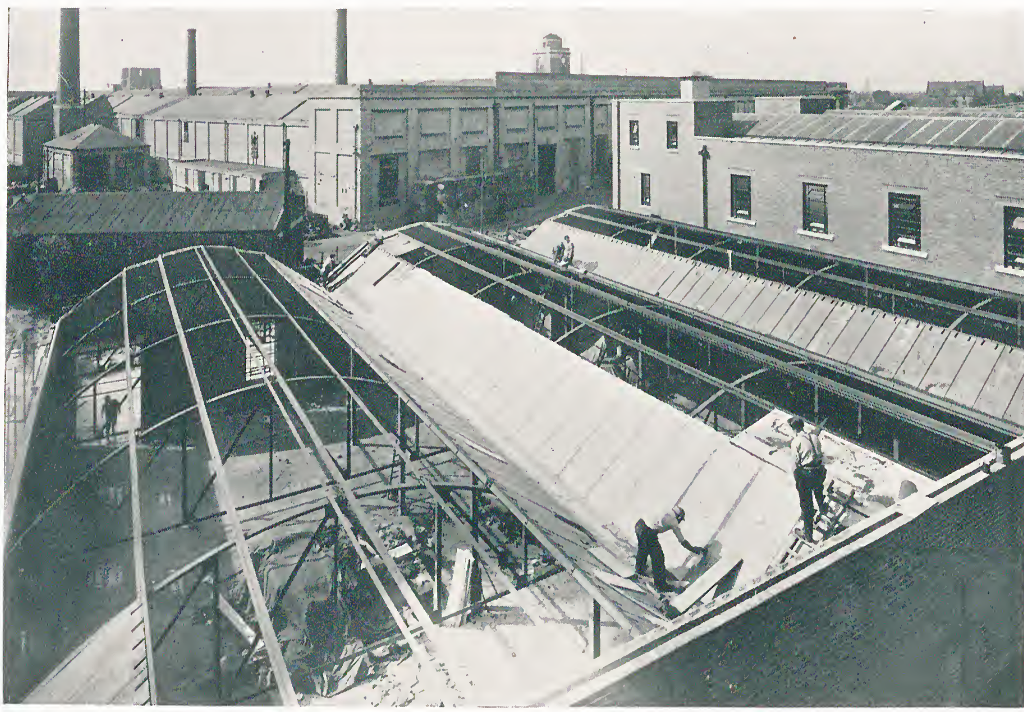
(Courtesy of William Briggs & Sons Ltd.)

"RUBEROID" STEEL DECK INTERLOCKING UNITS FINISHED WITH INSULATION BOARD AND TWO LAYERS OF "RUBEROID" ROOFING FELT.

(Courtesy of the Ruberoid Co. Ltd.)



" RUBEROID " STEEL DECK ROOFING UNITS.



" RUBEROID " STEEL DECK ROOFING UNITS. FINISH—" ASTOS " ROOFING ON INSULATION BOARD.

(Both photos by courtesy of the Ruberoid Co. Ltd.)

section there are step and box sections. Two forms of sheet "tile" are also made: the Canadian and Scandinavian, which are used in Northern countries for roofing houses.

Galvanising is a process of rustproofing by which the steel is covered with a coating of zinc. Galvanising varies in thickness and quality.

GALVANIZED FITTINGS

Weight of Rivets

⅜" × ¼"	-	57 Gross to 1 cwt.
½" × ¼"	-	52 " "
⅝" × ¼"		48 " "

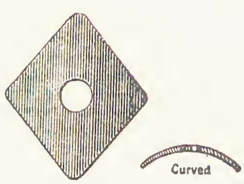
Weight of Bolts and Nuts

1½" × ¼"	-	20 Gross to 1 cwt.
1¼" × ¼"	-	22 " "
1" × ¼"	-	24 " "
¾" × ¼"	-	27 " "
½" × ¼"	-	28 " "

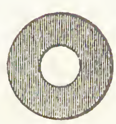
2½"	- -	22 Gross to 1 cwt.
3"	- -	19 " "

2¼"	-	24 Gross to 1 cwt.
2½"	-	21 " "
3"	- -	16 " "

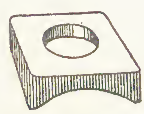
4" × 5/16"	diameter	-	5½ Gross to 1 cwt.
4½" × 5/16"	"	-	5 " "
5" × 5/16"	"	-	4½ " "
4" × ⅜"	"	-	4 " "
4½" × ⅜"	"	-	3½ " "
5" × ⅜"	"	-	3 " "



18 Gross to 1 cwt.



For ¼" Rivets and Nails: 57 Gross to 1 cwt.



11 Gross to 1 cwt.

Fig. 253.—Fixing accessories for corrugated iron.

There are four qualities described by the manufacturers in terms such as: 1. Standard. 2. Extra coated or specially selected. 3. Extra heavily coated. 4. Best double coated.

Lengths from 5 feet to 12 feet are made, with widths from 25 inches to 30 inches.

The gauge most commonly used is No. 24, and for this thickness purlins are usually spaced 3 feet centres.

Curved sheets and flashing sheets are also made.

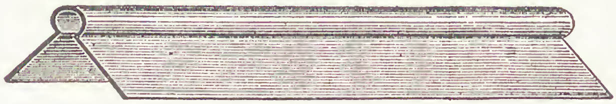
The end lap should be 9 inches to ensure weathertightness. Side lap varies from half to two corrugations. Fixing is by hook bolt to steel sections and by drive screw to timber. Hook bolts should be $\frac{5}{16}$ inch diameter and of suitable length. They should be spaced one at each side lap and one between laps; that is at about 12-inch centres for 8/3-inch corrugation sheets, and at about 15-inch centres for 10/3-inch corrugation sheets

Drive screws, cone-headed nails, or screw nails for fixing to timber should be spaced at 6-inch centres in end laps, also along top and bottom purlins. Along intermediate purlins they should be spaced at 9 to 12-inch centres.

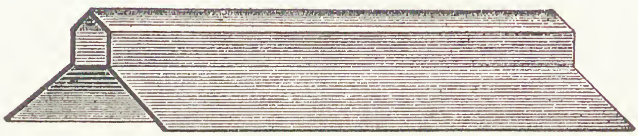
With each bolt or screw one galvanised curved embossed washer should be used. Alternatively, one curved round or diamond washer with one lead or bituminous felt washer placed between iron washer and sheet should be used.

Seam bolts should be used to make watertight joints, independently of fixings to purlins. Seam bolts should be spaced 15 inches to 18 inches centres along the side laps for single and lap and a half, and at 9 inches staggered or zig-zag pitch for double laps.

GALVANIZED RIDGING AND LOUVRE BLADES

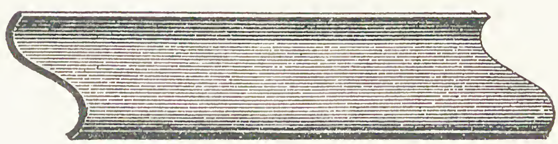


Girth 12″ to 36″. Gauge 16 to 26. Length about 6′ 0″

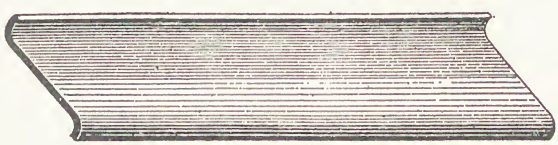


Girth 12″ to 36″. Gauge 16 to 26. Length about 6′ 0″.

16 Gauge up to ⅛″ thick, maximum length 6′ 0″
Under 16 Gauge, " " 8′ 0″



Girth 11″—16 Gauge up to ⅛″ thick, maximum length 6′ 0″
Under 16 Gauge, " " 8′ 0″



Girth 11″—16 Gauge up to ⅛″ thick, maximum length 6′ 0″
Under 16 Gauge, " " 8′ 0″

Fig. 254.

End laps should have one bolt through junction or ply of end and side laps, and three between side laps. Seam bolts should be $\frac{1}{4}$ inch diameter.

In fixing sheets, start at the bottom and work upwards. All fixing holes should be made through the crown of the corrugation. The exposed edge of side laps should face away from the prevailing wind.

Owing to the "greasy" nature of a galvanised surface the new sheets do not take oil paint well. Bituminous paint binds well to the surface and is more durable than oil paint.

The following is a table of gauges, corrugations, and lengths. As an example, under "size," 16 B.G.5/5 inch corrugations, means 16 gauge with five 5-inch corrugations to the width, which gives a sheet 25 inches wide. Other widths can be calculated in the same way.

Sizes and Weights of Galvanised Corrugated Sheets

Approximate Number of Sheets per ton

SIZE.	5 ft.	5½ ft.	6 ft.	6½ ft.	7 ft.	7½ ft.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	11 ft.	12 ft.
16B.G. 5/5-inch corrugation	70	64	58	54	50	47	44	41	39	37	35	..	..
,, 6/5-inch ,,	59	54	49	45	42	39	37	35	33	31	29	..	..
18B.G. 5/5-inch ,, } ,, 8/3-inch ,, }	86	78	72	66	62	57	54	51	48	45	43	..	..
,, 6/5-inch ,, } ,, 10/3-inch ,, }	74	67	62	56	53	50	46	43	41	39	37	..	..
20B.G. 8/3-inch ,,	114	104	95	88	81	76	71	67	63	60	57	..	..
,, 10/3-inch ,,	95	86	79	73	68	64	59	56	53	50	47	43	39
22B.G. 8/3-inch ,,	139	127	116	107	99	93	87	82	77	73	69	63	58
,, 10/3-inch ,,	116	105	97	90	83	78	73	68	65	61	58	52	48
24B.G. 8/3-inch ,,	168	153	140	130	120	112	105	98	93	88	84	76	70
,, 9/3-inch ,,	154	140	128	119	110	103	96	90	85	81	77	70	64
,, 10/3-inch ,,	140	128	117	108	100	94	88	83	78	74	70	64	58
26B.G. 8/3-inch ,,	223	203	186	172	159	149	139	131	124	117	111	..	..
,, 9/3-inch ,,	204	186	170	157	146	136	127	120	113	107	101	..	..
,, 10/3-inch ,,	186	169	155	143	133	124	116	109	103	98	93	..	..
28B.G. 8/3-inch ,,	240	219	200	185	172	161	150	141	133	126	120	..	..
,, 9/3-inch ,,	220	200	183	169	158	147	137	129	122	116	110	..	..
,, 10/3-inch ,,	200	182	167	154	143	133	125	118	111	105	100	..	..
30B.G. 8/3-inch ,,	288	264	240	222	206	192	180	170	160	151	144	..	..

CHAPTER 16

ASPHALT AND BITUMINOUS FELT

ASPHALT is applied as a mastic and spread over the supporting surface. Bituminous felts are supplied in rolls and laid and nailed to boards or laid and cemented with mastic to concrete surfaces. The better-quality felt roofings are " built-up " in layers, each layer being cemented to the layer below with bituminous mastic.

ASPHALT

The mastic asphalt used for roofing is a natural bituminous material incorporating a fine grit aggregate. For pavings and wearing surfaces the aggregate is coarse.

Coloured asphalts are made for floorings.

Asphalting is a specialist's job, and there are many firms undertaking the work and giving a guarantee of durability.

The material is resilient, does not readily crack if the supporting structure moves slightly, and is impervious and durable. When repairs are necessary they can be easily effected by skilled workmen.

Mastic Asphalt.—From a builder's point of view the term " asphalt " can be defined fairly easily. The material with which he is familiar is delivered on his job in the form of blocks or cakes, generally either round, square, or hexagonal in shape, bearing the brand of the manufacturers, and that material is known as " mastic asphalt." The term " mastic " merely indicates that the asphalt has been made in a certain way, and distinguishes it from other forms such as compressed asphalt or steam-rolled asphalt, etc. It is true that mastic asphalt can be, and is, used for making roads, but for that purpose it is manufactured somewhat differently from the material used for building work.

What then does the term " mastic " mean ?

It means that the asphalt is sufficiently rich in bitumen and fine mineral matter to enable it to be laid in a molten state and spread into position with hand tools known as " floats," as distinct from compressing it into position with hot irons or steam rollers. One of the earliest types of asphalt laid in modern times was mastic asphalt, and was first used in Paris in 1835, the material being made in France. This accounts for the fact that in the building industry it is generally called " asphalte " with an " e," as that is the French way of spelling it.

This French asphalt was a natural material found in the earth, and was obtained from asphalt mines in a region in the departments of Haute Savoie and Ain, near a small town called Seyssel, on the Rhône. Hence the origin of the term " Seyssel Asphalt " under which asphalt from that district is still known. Although in some cases the deposits are worked more like a stone quarry than a coal-mine, it is sometimes necessary nowadays to go down much deeper, and there is a mine which the writer has visited where descent has to be made in a cage down a shaft very similar to those used in coal-mines.

Bitumen.—The material gained from an asphalt mine is a rock which, although hard, is porous, and the pores are entirely or partly filled with bitumen.

It is generally believed that the bitumen was formed by the decomposition of animal or vegetable matter or both, in the absence of air, and is very closely akin to crude petroleum.

Most of the world's petroleum was formed in a similar way, and consists of widely varying proportions of bitumen dissolved in a very complex mixture of hydrocarbons, the bitumen itself being a highly complex mixture of hydrocarbons and other compounds. This suggests that the bitumen which permeates the porous rock may have been derived from petroleum which originally contained volatile constituents, and in the course of time these either " evaporated off " or underwent a chemical change, leaving behind, or becoming converted into, the sticky black substance which we know as bitumen.

As crude petroleum itself may be defined as " bitumen in a liquid state," we ought strictly to call what we are concerned with " asphalt bitumen," to distinguish it from other forms.

As bitumen is only formed extremely slowly in nature nowadays, we do not know, however, whether it was formed direct from organic matter or as a residue derived from natural crude petroleum in the manner described above, but whatever the origin and mode of formation, it is so closely allied to petroleum chemically that the study of the properties of bitumen is a branch of the study of petroleum.

We have therefore learned that bitumen is found in nature permeating the pores of certain rocks, but it is also found in a number of other forms, which vary a great deal in their appearance and other physical properties.

The largest commercial source of naturally occurring bitumen to-day is the well-known Trinidad " Lake," in the island of that name, off the north-east coast of South America. This bitumen is known commercially as " Epuré," and has been continuously exploited for many years. In the case of Seyssel asphalt we have seen that the bitumen is " mixed up " in solid rock, but in the case of Trinidad Lake bitumen it is the other way round, and finely powdered mineral matter is found dispersed throughout the bitumen. In refined Trinidad Lake bitumen only approximately half is pure bitumen, and just under half is clay and other mineral matter,

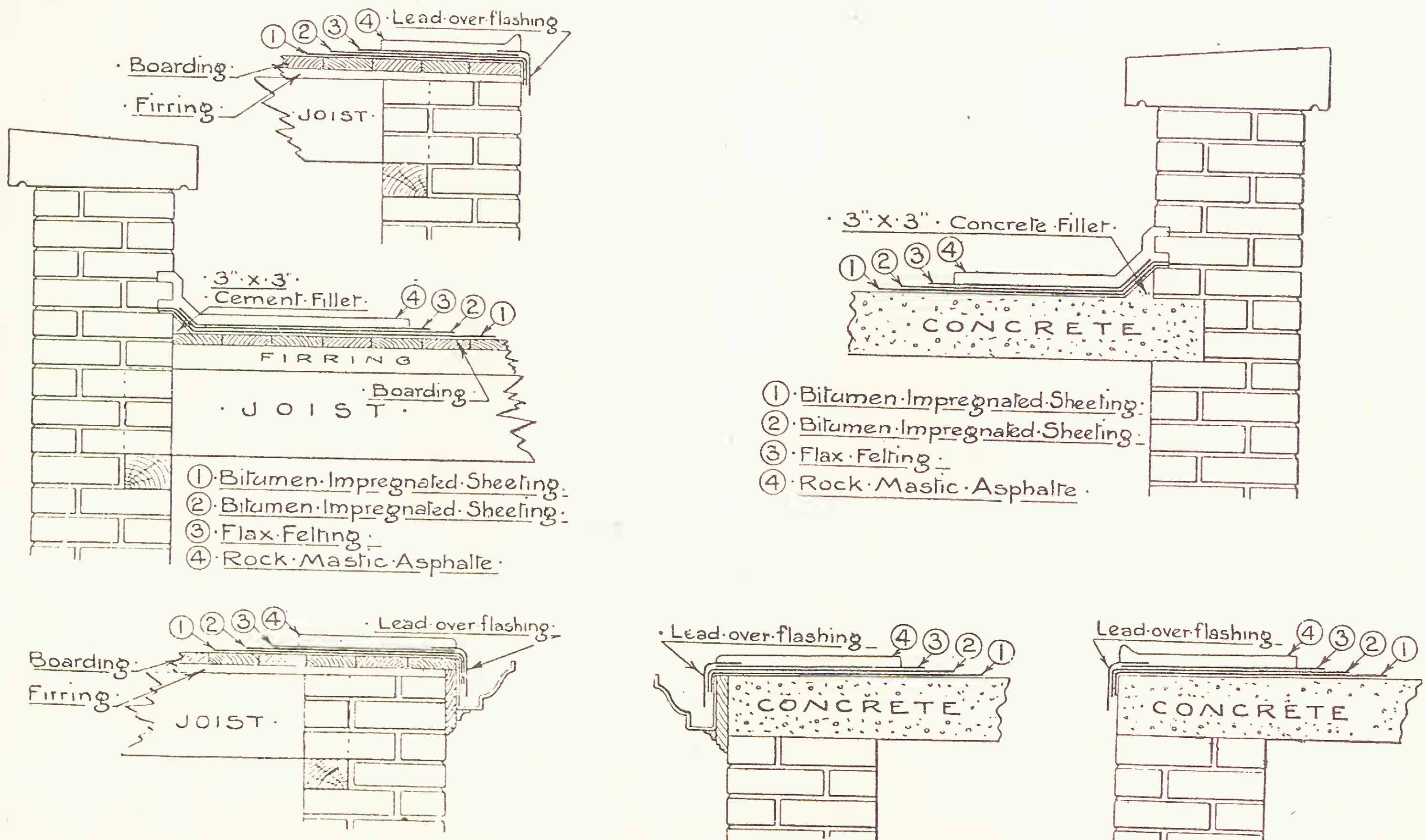


Fig. 255.—Details of asphalt roofing on boards and on concrete, at parapets, eaves, and verges

while as found in the Lake only about 40 per cent. is pure bitumen. There are certain theories as to the origin of this Lake, but broadly speaking it can be said that bitumen was formed in the same way as that in the Seyssel asphalt, *viz.* either direct from decaying soft parts of animal and plant remains, or from crude petroleum after the lighter constituents had been removed or had undergone a chemical change, leaving a more viscous part behind.

Residual Bitumen.—It will occur to the reader that if Nature in certain and perhaps in all cases makes bitumen in this way, could it not be made commercially direct from crude oils obtained from petroleum oil wells ? The answer is that it can and is so made from certain crude oils having what is called an asphaltic base. Such bitumen is generally called " residual " bitumen, and is used extensively, particularly for road work. The term "residual" is sometimes used disparagingly, suggesting that such bitumen is inferior to that made by Nature, but it is open to question whether that is entirely correct. It is true that it undergoes a certain process of manufacture, but it is not, strictly speaking, manufactured at all, because all that happens in most cases is that the lighter oils are driven off, and the bitumen which was there in the crude oil all the time remains behind. It is thus merely isolated or segregated and not produced by any chemical change in the refinery. The bitumen was put there by Nature, and is in that sense just as natural as the bitumen in the Trinidad Lake. It is certainly not correct to call them all " synthetic " bitumens, because nothing is added. Residual bitumens should, however, be distinguished from what are called " blown " bitumens, which are partly artificial, because in addition to the natural bitumen indigenous to the oil, they contain other bitumen formed by action of oxygen in the air upon constituents of the crude petroleum. These " blown " or oxidised bitumens are used chiefly for certain kinds of bituminised felts.

It is worth noting here that bitumen made direct from petroleum is separated out in some of the most scientifically equipped works and in the most highly elaborate and expensive plants to be found in any industry to-day.

Further, even the Lake bitumen could not be used in the form it is found, and has to be refined. The word Epuré, itself, is a French word meaning refined, or made pure. The crude bitumen has to be heated in boilers to drive off water and other matter before it is rendered suitable for employment in industry, and is therefore itself manufactured to some extent.

Process of Manufacture.—We have seen that Seyssel asphalt is a natural rock found in the earth, and the mastic asphalt made from it consists only of the rock itself crushed to fine powder with refined bitumen added.

The process of manufacture consists in mixing the ground rock with bitumen in a heated boiler or " Cooker " fitted with revolving arms or blades for sufficient length of time to enable the bitumen to become evenly distributed throughout, and the resultant hot fluid mass is then poured into moulds and allowed to cool.

When the moulds are removed the cakes can be conveniently stacked or sent where required, and all that is necessary to render the asphalt fit for immediate use is to remelt it. One of the chief properties of the bitumen in the asphalt is, therefore, that it can be remelted without deterioration, provided sufficient care is taken not to burn it.

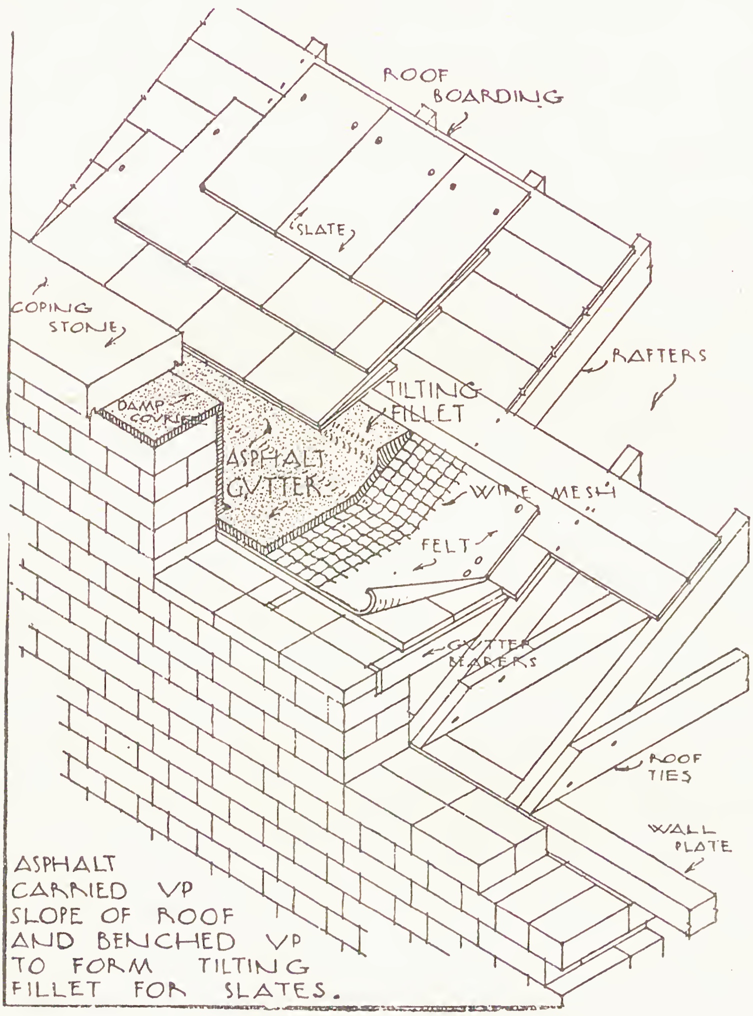


Fig. 256.—Asphalt gutter.

Clean graded grit or granite chippings and a further quantity of neat bitumen may be added in the remelting cauldron in order to modify the properties of the asphalt as laid to suit the particular job in hand.

Waterproofing Qualities.—From the point of view of its use in building construction, however, its waterproofing qualities are those which count most, and those which explain the continued use of asphalt for dampcourses, basements, and roofs.

This property was well known in very earliest times, and canoes and dugouts were made watertight with bitumen by primitive peoples. Probably Noah used it for the Ark as long ago as 2500 B.C. Although the version of the Deluge story with which we are familiar speaks of treating the Ark with " pitch," this term refers to naturally occurring bitumen, and not to coal-tar pitch, which was of course unknown at that time, and in the Latin text the word is spelt as "bitumen."

Other qualities of asphalt which contribute to its popularity are that it is comparatively noiseless and soft to walk on, is hygienic, jointless, and dustless, and as new sections can be incorporated with old ones by annealing or "marrying" them together, it is easily repaired if damaged. Also it can be applied as a continuous covering around projections and slopes, and has the property of responding to expansion and contraction due to temperature changes and other stresses.

Bitumen is found or can be made in varying degrees of hardness or "penetration" as it is called, but it could not, except for a few special purposes, be applied to a building in its natural state, because it would be too soft, and would gradually flow out of position. The natural rock is therefore added, partly to make it harder and partly to prevent it melting or flowing at ordinary temperatures. Conversely, it may be said that as the natural rock is not sufficiently rich in bitumen to make a mastic, it must be enriched to fill up all voids to make the asphalt sufficiently waterproof and to enable it to be spread into position. The added bitumen helps the solid particles to move over one another, and so also acts as a kind of lubricant.

Seyssel asphalt has stood the test of time as an excellent material for building work. It has been continuously used on important buildings in this country for nearly a century, and has established its durability in positions exposed to all the rigours of our uncertain climate.

The deposits in the Seyssel region are, however, not the only ones which exist. There are, for example, areas in the department of Gard in France, and the Neuchâtel mines in the Val de Travers in Switzerland are well known.

A further source of asphalt is in Germany, and the asphalt rock which comes from there is known as Limmer asphalt, after a place near Hanover where it was first discovered.

There are large areas of asphalt rock in the region known as Vorwohle, which yield some good material. There are also deposits of good rock in the south of Sicily at Ragusa, which must not be confused with the port of Ragusa on the east coast of the Adriatic.

Similarly, there are other sources of bitumen besides the Trinidad Lake, *e.g.* the Bermudez asphalt lake in Venezuela. There are also deposits in various parts of the United States, in the East Indies, and in Mesopotamia. Some of these special characteristics render them suitable for special purposes, such as best-quality acid-resisting mastic asphalts exposed to relatively high temperatures.

Bitumen is recognised as one of the most complicated chemical substances known to science, and its wonderful properties can easily be upset if proper care is not taken in handling it in the course of its conversion into asphalt. The asphalt contractor is a specialist, and his operatives are highly skilled workmen. He has to take a building as he finds it, and special forms of construction present difficult problems which have to be overcome.

If settlements occur, or undue strains and stresses are set up, they cannot expect it always to " remain put."

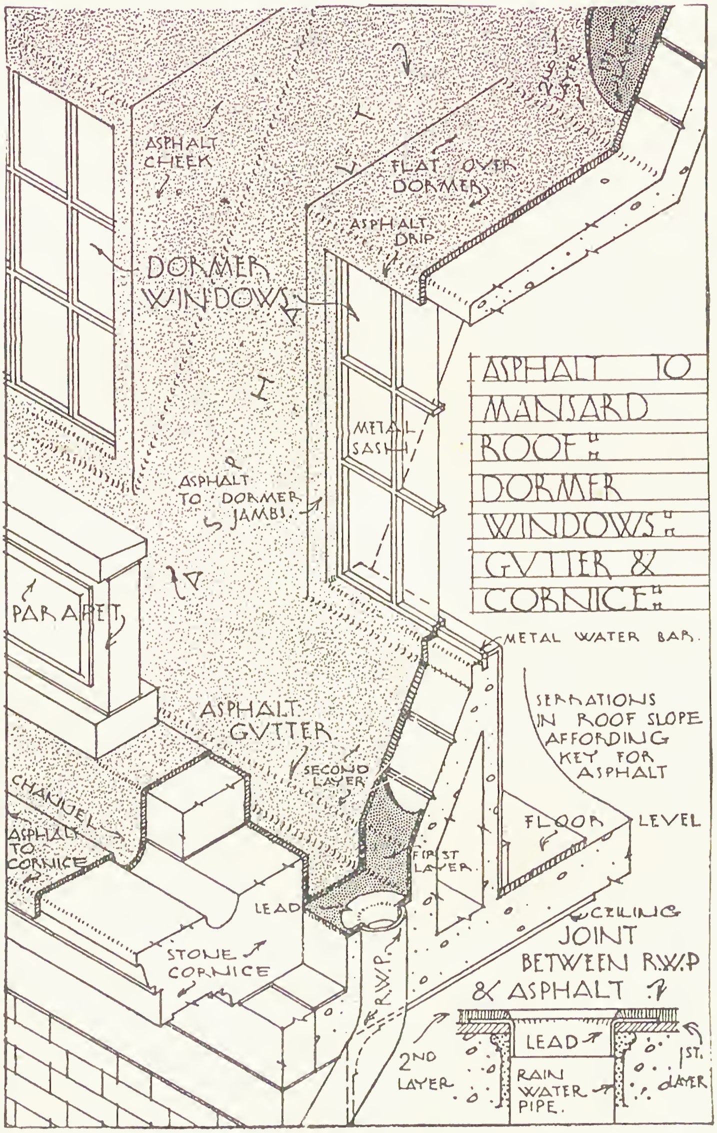


Fig. 257.—Asphalt roof with dormer

" PERMANITE " AND " PERMAPHALT "

These are proprietary roofing asphalt preparations supplied by Messrs. Permanite, Ltd. " Permanite," for roofs of light construction, either boarded or concrete, flat or sloping roofs, is built up in two or more layers and sealed together with hot bitumen.

" Permaphalt " is a combination of sheet asphalt and mastic rock asphalt, and is suitable for flat roofs to be used for heavy work, such as use as a roof garden. It is constructed of two layers of sheet asphalt, a layer of sheeting felt, and is finished on the top with either a half-inch coat of hot asphalt or with a $\frac{3}{4}$-inch thickness in two coats of hot asphalt.

Permanite mastic rock asphalt is used also for flat roofs, whether boarded or concrete, and is usually laid $\frac{3}{4}$ inch in two coats. On concrete roofs it is laid hot direct on the concrete, and on boarded roofs a layer of felt is first put down to form a key and prevent the asphalt going through the joints. Expanded metal reinforcement is also used for a boarded roof, as the metal considerably increases the tensile strength of the asphalt.

Another preparation made by the same company for light sloping boarded roofs consists of a bitumen felt of the rubber type, which is laid on in one layer, sealed at the joints with bitumen mastic, and nailed with galvanised clout nails. The pure bitumen used is acid-proof and proof against atmospheric conditions.

Constructional Details.—On Boarded Roofs.—The first layer of Permanite is nailed at random to the boarding, then the second is sealed to the first with hot bitumen, and the third layer is then laid over the second in a similar manner, the three layers breaking joint. The whole area is then coated with hot bitumen and drygrit embedded.

On Concrete.—The Permanite is laid in two layers on concrete, the first being sealed to the concrete with hot bitumen, and then the second is sealed to the first in a similar manner, each layer breaking joint and the surface being coated with hot bitumen and grit.

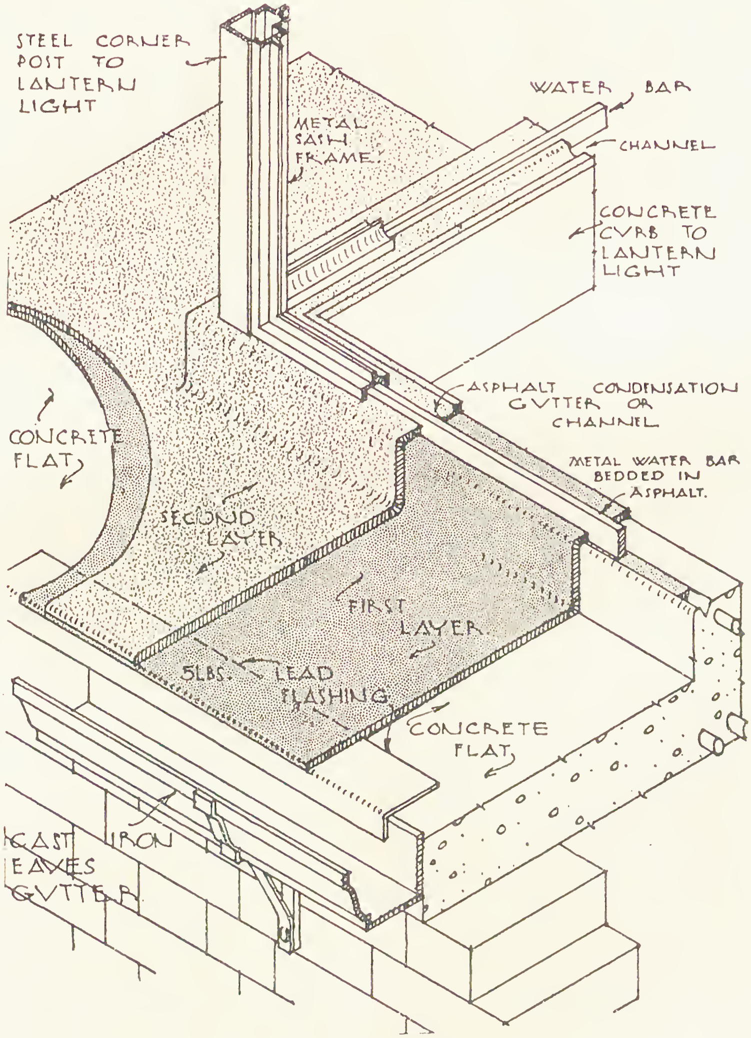


Fig. 258.—Asphalt flat roof

The Eaves are constructed with an apron of either felt or lead screwed to an eaves fascia and tacked over the roof boarding at the top and turned down into the gutter at the bottom. The two layers of roofing are continued over the upper part of the lead or felt and finish flush with the eaves fascia.

An alternative method is to use a special zinc kerb, where a 2-inch gravel surface is laid over the Permanite. This kerb is similar to the lead or felt apron last described, in that it is laid over the lower layer of roofing and turned down over the fascia, but in addition it is turned upwards as a stop to the gravel surfacing and it is perforated at intervals for the drainage of the roof.

Permaphalt Asphalt, in which the two layers of felt are sealed together with hot bitumen, and reduces the liability to cracking, has between the asphalt and the sanded felt a layer of sheeting felt.

On a Boarded Roof two layers of sheet asphalt are laid, the first with hot bitumen and finished on the top with ½-inch thickness of mastic rock asphalt.

On Concrete there must be two layers of sheet asphalt, the first being sealed to the concrete with hot bitumen and the second sealed similarly to the first. Upon this is a layer of sheeting felt and finished on top with ½-inch thickness of mastic rock asphalt.

The specification for a *Super Permaphalt* roof on a boarded flat is two layers of sheet asphalt, the first being laid to the boarding at random and the second sealed to the first with hot bitumen. Over this a layer of sheeting felt is laid, finished on top with ¾-inch thickness of rock asphalt, laid in two ⅜-inch coats.

Where the eaves are finished with lead aprons, the asphalt is finished at its outer edge over the upper surface of the lead with a bullnose.

Over a Gutter an asphalt drip is formed by reinforcing the asphalt with expanded metal.

Against Vertical Walling the asphalt is turned up at least 6 inches and let into a raked-out joint which must be cemented at completion. In the corner, where the upright asphalt joins the horizontal, a triangular fillet is formed in asphalt as a strengthening.

Flat Roofs in asphalt over boarding are laid in two layers of rock asphalt on a layer of felt, the two layers being each ⅜-inch thick. On concrete, only the two ⅜-inch layers of rock asphalt are required.

Finish with Slates.—Where a boarded flat is covered with asphalt above a sloping slate roof the asphalt is turned over the nosing of the flat and continued three-quarters down the length of the top slates. It is also necessary to continue the felt down the vertical face of the nosing and also over the slate covered by the asphalt.

As a Finish to the Verge a 3×2-inch wood angle fillet is nailed to the upper face of the roof boarding and the asphalt is carried up over the fillet on expanded metal reinforcement and a layer of felt. The boarding being carried out over the fascia, this forms a 3-inch cheek and a drip underneath.

A Parapet Gutter is formed in asphalt by turning the asphalt 6 inches up against the vertical brickwork and tucking it into a raked joint in the brickwork. A solid asphalt tilting fillet is formed under the bottom corners of slates and an asphalt angle fillet is formed in the angle between the horizontal bed of the gutter and the vertical face of the brickwork. The felt is run down the roof, under the tilting fillet, over the gutter boarding, and finished against the brickwork. Over the felt expanded metal is laid which resists any creeping tendency on the part of the asphalt.

A Valley Gutter is formed of ¾-inch asphalt in two coats on felt and expanded metal, and turned up under the bottom courses of the slates and formed into a solid asphalt tilting fillet.

Dampcoursing.—Asphalt is also used for the vertical and horizontal dampcoursing of walls in the manner already described.

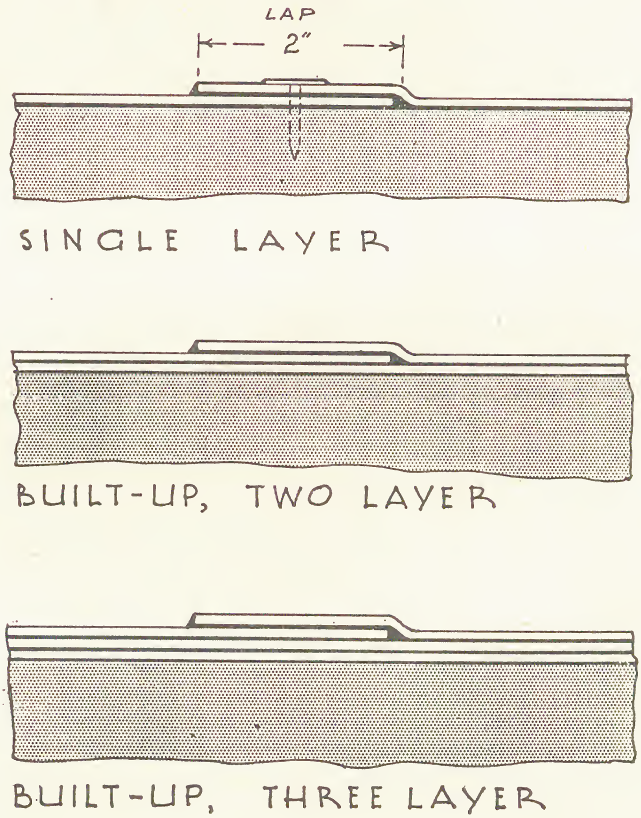


Fig. 259.

BITUMINOUS FELTS

These roofing materials consist of a "base" such as wool-felt fibre or asbestos fibre, saturated in asphaltic bitumen and afterwards coated on both sides with bitumen. It is suitably surfaced to prevent sticking in the roll.

The material is made by a number of firms and sold under brand names. Thicknesses and qualities vary. The best bituminous roofing felts will remain weatherproof for many years. They can be used to cover both pitched and flat roofs.

Reinforced Bituminous Felt.—The difference between this felt and ordinary bituminous felt is that a layer of jute, hessian, or canvas is incorporated. This gives the material high resistance to tearing through sheer or tensile stress.

Fire-resisting Felt.—Bituminous felts do not readily take fire, and if a non-inflammable base is used they have high resistance to fire. Fire-resisting felts incorporate asbestos fibre as the base.

Coal-tar Felts.—These are inferior to bituminous felts and are suitable only for temporary buildings. They are usually sand finished to prevent the tar running in the heat of the sun.

Underfelt or Sarking.—This is a felt especially intended for use under tiles or slates on pitched roofs. An underfelt should be a good-quality bituminous felt, but it need not be of the thicker grade.

Where the felt is laid on the rafters (without boarding) it should be a reinforced felt to reduce the possibility of tearing as the felt sags between the rafters. In laying, underfelt should be turned over the fascia and the lower edge should lap over the back of the gutter so that any water penetrating the roofing can drain into the eaves gutter.

Single-layer Roofing.—This is suitable for pitched roofs although it must be realised that one layer is more easily penetrated than several.

The felt is nailed to boarding with 11 S.W.G. galvanised nails, $\frac{3}{4}$ inch long in accordance with the manufacturer's instructions, of which some examples are described below.

The felt is cemented to a concrete surface with a bituminous mastic, as described below.

Built-up or Multi-layer Roofing.—For permanent buildings the felting is applied in layers cemented together *in situ* with a suitable mastic.

Most manufacturers prefer to have built-up felting laid by their own workmen. They then guarantee the roofing.

Flashings on permanent buildings should be carried out in lead, zinc, or copper. Felt can be used for this purpose if corner fillets are provided, but it tends to crack when bent and does not work so easily as lead.

Fig. 259 illustrates comparative details of single-, two-, and three-layer roofing. Laps should be at least 2 inches, put together in liquid mastic, and nail heads and margins should be coated with mastic.

On pitched roofs felting may be laid :

(*a*) from verge to verge, as in Fig. 260, or
(*b*) from eaves to ridge, as in Fig. 261.

Laps should be made so that the water runs over and not into the joint.

Verges and eaves edges should be rounded so that the felt can be turned over the edge without cracking.

Lion Roofing is composed of the finest long-fibred raw felt, compounded with pure bitumen, with an extra coating of horn-like bitumen on both sides. It is claimed for this felt that amongst its advantages are the facts that it requires no re-dressing, that it is absolutely watertight, and will not crack or dry out. Not being coated with gravel there is no danger of clogging gutters. It is suitable for use in any climate, and is rot- and acid-proof. It is supplied in $\frac{1}{2}$-, 1-, 2-, and 3-ply rolls.

This roofing is suitable for laying on the slope or flat, and to form gutters and flashings against vertical work. When laying from ridge to gutter the work should be begun at the rear end and proceeded with towards the front. When laid lengthwise, *i.e.* parallel with the gutter, the work should be commenced at the gutter and proceeded with upwards, the upper sheet being lapped over the lower at least 2 inches. The laps require to be cemented with a special liquid cement supplied,

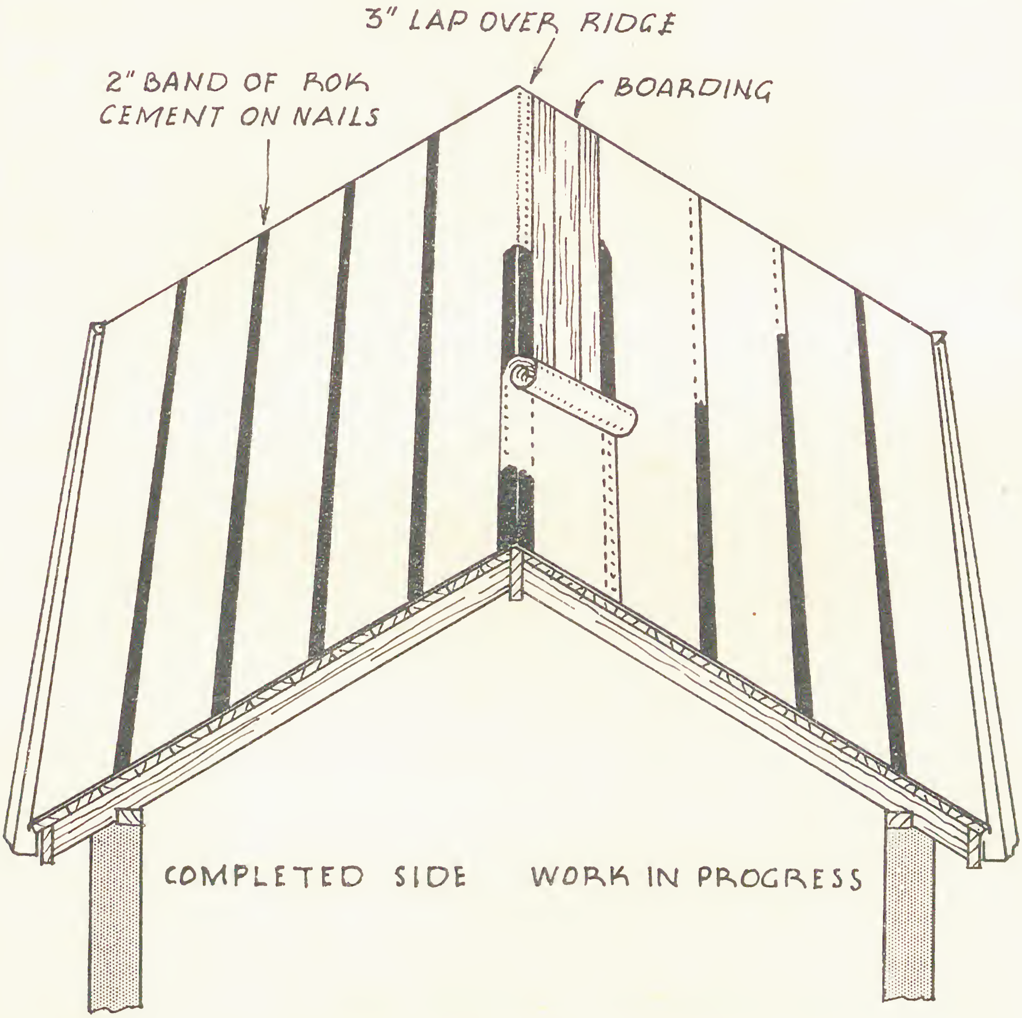


Fig. 260.—Verge-to-verge or horizontal laying.

and the nails driven through both lapped sheets at distances 2 inches apart and 1 inch from the edge. The roll should be laid inside downwards to ensure a close fit; and the nailing operation should be begun at the top and worked down, or at the centre and towards the ends. This is an important point, as it prevents buckling between the nail heads and enables the seams to be laid smoothly. A practical hint to assure that the sheet that is being nailed should lie flat is to lay a heavy plank over it whilst nailing. Cross joints should be given a 3-inch lap, and must be very carefully cemented, and coated over on the outside.

At Gable Ends and Eaves the roofing should be bent over and extended down far enough for the water to drain off without coming into contact with the woodwork. And along the ridge a strip should be laid about

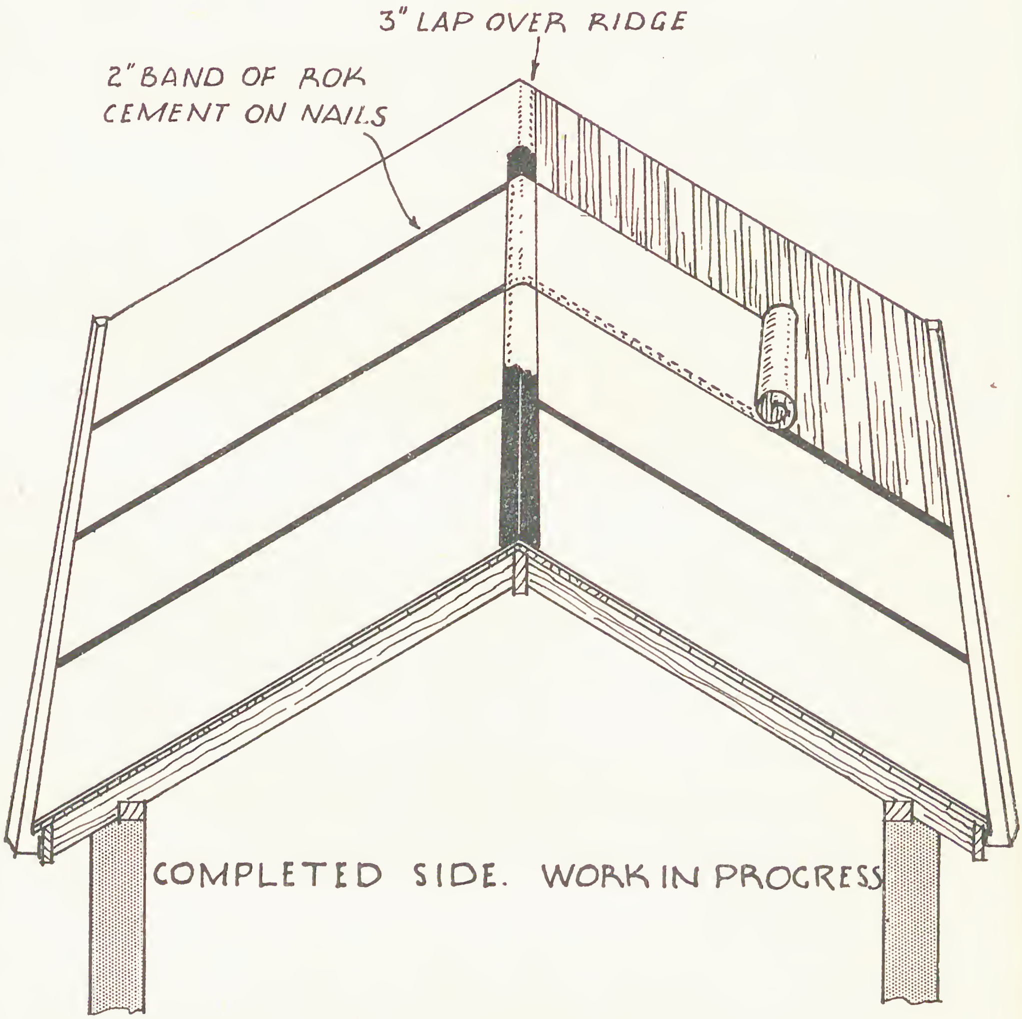


Fig. 261.—Eaves to ridge or vertical laying.

18 inches in width, lapping over the ridge on both sides. This should be thoroughly cemented and nailed down.

Valleys must be in double thicknesses, solidly cemented together and well lapped.

Gutters also should be of double thickness, cemented, and of sufficient width to cover the gutter and extend under the roofing for 6 inches. The roofing should not be nailed to the bottom or sides of the gutter and plenty of cement should be used at the outlet. The edges of the roofing should extend well down into the down spout.

Flashing round chimneys and against parapets should be turned up at least 4 inches and cemented and counter flashed with a strip of roofing 12 inches wide lapping one half on the roof, and the other up the side. The edge must be fastened with a wooden cleat and thoroughly coated with cement.

This roofing should not be laid, if possible, in severely cold weather, and the roof boarding must be cleaned of projecting knots and nails.

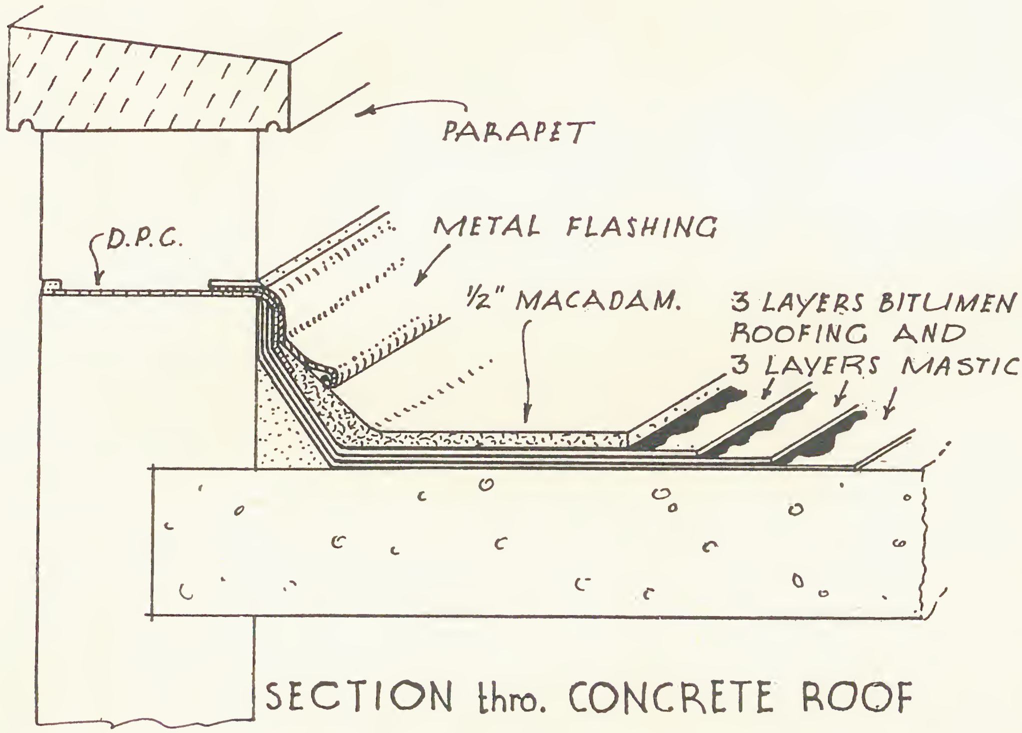


Fig. 262.—" Macasfelt " roofing on concrete flat roof.

Natural Mineral Rock Asphalt is to be obtained from Messrs. Engert & Rolfe, and though used very extensively for the vertical and horizontal dampcoursing of walls, it is also used as a roof covering with every success.

On Concrete Roofs it is laid from ¾-inch to 1-inch thick in two layers, and for heavy traffic a third coat is added specially hardened with Bridport grit or granite chippings. Gutters are lined with two or three coats and have fillets in the angles. Dormer cheeks should have two coats of asphalt also. Against vertical brickwork an asphalt skirting is constructed at least 6 inches high, with a fillet in the angle, and the uppermost edge tucked into the brickwork, all as already described.

On Boarding, vertical faces, such as cheeks to dormers, stand better in rock asphalt if expanded metal is used as a reinforcement. A section through the cheek consists of boarding, flax felt, metal reinforcement, and two layers of rock asphalt. Gutters also are more durable when reinforced in the same manner. *Roof Lights* should have the asphalt turned up against the kerbing and run round over the top of the kerbing and under the roof light frame.

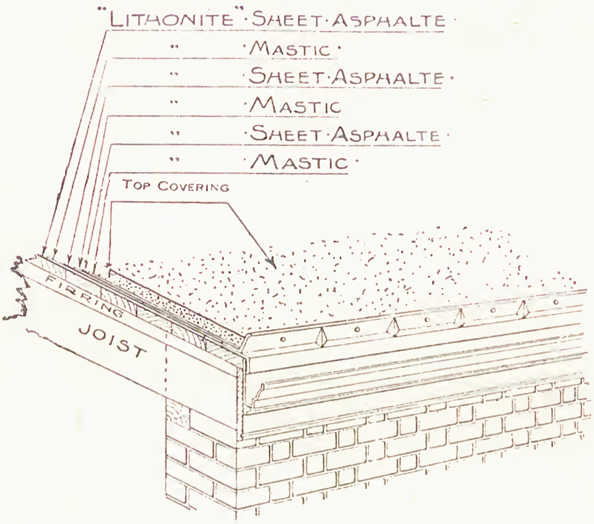


Fig. 263.—" Lithonite " roofing, boarded flat, showing eaves.

Lithonite is a laminated built-up asphalt roofing designed to give the maximum of elasticity, and is particularly useful in roofing buildings in which, either owing to the working of machinery or the close proximity to railways or heavy road traffic, there is considerable vibration to be resisted. It is also particularly suited to buildings subjected to subsidence, or where severe climatic extremes are experienced as in coastal towns, " Lithonite " having an upper protective covering.

It is laid on the job by the manufacturers' (Messrs. Engert & Rolfe's) workmen, and consists of layers of " Lithonite " sheet asphalt, and sealed together with applications of mastic applied hot. Each layer is applied separately with the joints broken in all directions, and the upper surface receives a sealing and finish coat of " Lithonite " mastic or varnish.

It is claimed for this preparation that it is absolutely and permanently waterproof, fire-resisting, impervious to weather, resists to the utmost extent the effects of expansion and contraction, settlement, storms, fire, and the severe traffic or the handling of heavy goods. It is an exceptionally efficient insulator and a non-conductor, complies with all building by-laws, and is a fire-insurance roof.

On Boarded Flat Roofs this preparation comprises six layers, starting from the boarding with sheet asphalt, followed by mastic, then another layer of sheet asphalt, followed by mastic, and two similar courses covered by a top covering of loamy sand and gravel, hoggin concrete, tar paving, or bituminous macadam.

Zinc retaining kerbs are fixed at the eaves when the sand and gravel finish is used, but are not required with concrete, tar paving, or bituminous macadam.

For Gutters and against parapet walls the same six-layer preparation is used, and a $4\frac{1}{2} \times 3$-inch wood angle fillet is fixed over the first layer of sheet asphalt which is run into the angle, the other five coverings being laid *over* the angle fillet, and a lead or zinc flashing is let into a raked-out joint and turned down over the top covering of the roofing.

Outlets to Gutters are formed of metal piping through the parapet wall, the end of the outlet being framed round with a perforated wood kerb.

A Flat Roof in Wood, finishing into a sloped roof, as in a mansard roof has a metal (zinc) gravel kerb round the outside edge of the flat to stop the gravel against, and the base of zinc kerb is carried down as a flashing over the slating on the sloping roof. The preparation covering the flat is the five-layer method already described; and should there be any wood parapet running round the flat, the posts for this are bedded on a

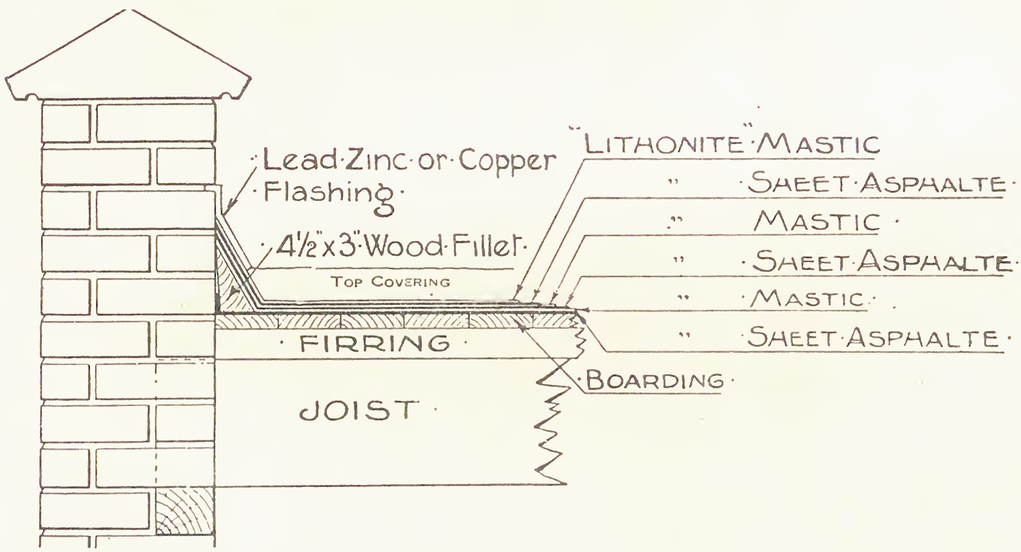


Fig. 264.—" Lithonite " roofing, boarded flat, showing parapet.

zinc under-flashing, which is also flashed round the base of the post and covered with a zinc cover flashing tacked to the post above it.

Concrete Flat Roofs have a bottom layer of " Lithonite " sheet asphalt sealed to the concrete with " Lithonite " mastic. Where it is required to save expense, a three-layer preparation is advised, consisting of one layer of extra heavy asphalt and two layers of mastic.

The top finish as used on wood roofs may also be added, but this is not necessary. In many instances the upper surface is finished with a dressing of mastic and grit.

For Parapet Walls it is recommended that the concrete be turned up into the angle at the base of the wall, and the roofing is turned up over this and flashed with a lead or zinc flashing let into a brickwork joint.

Eaves are flashed in lead turned down into the gutter over the first covering of sheet asphalt, the remaining layers being continued over the flashing to the edge.

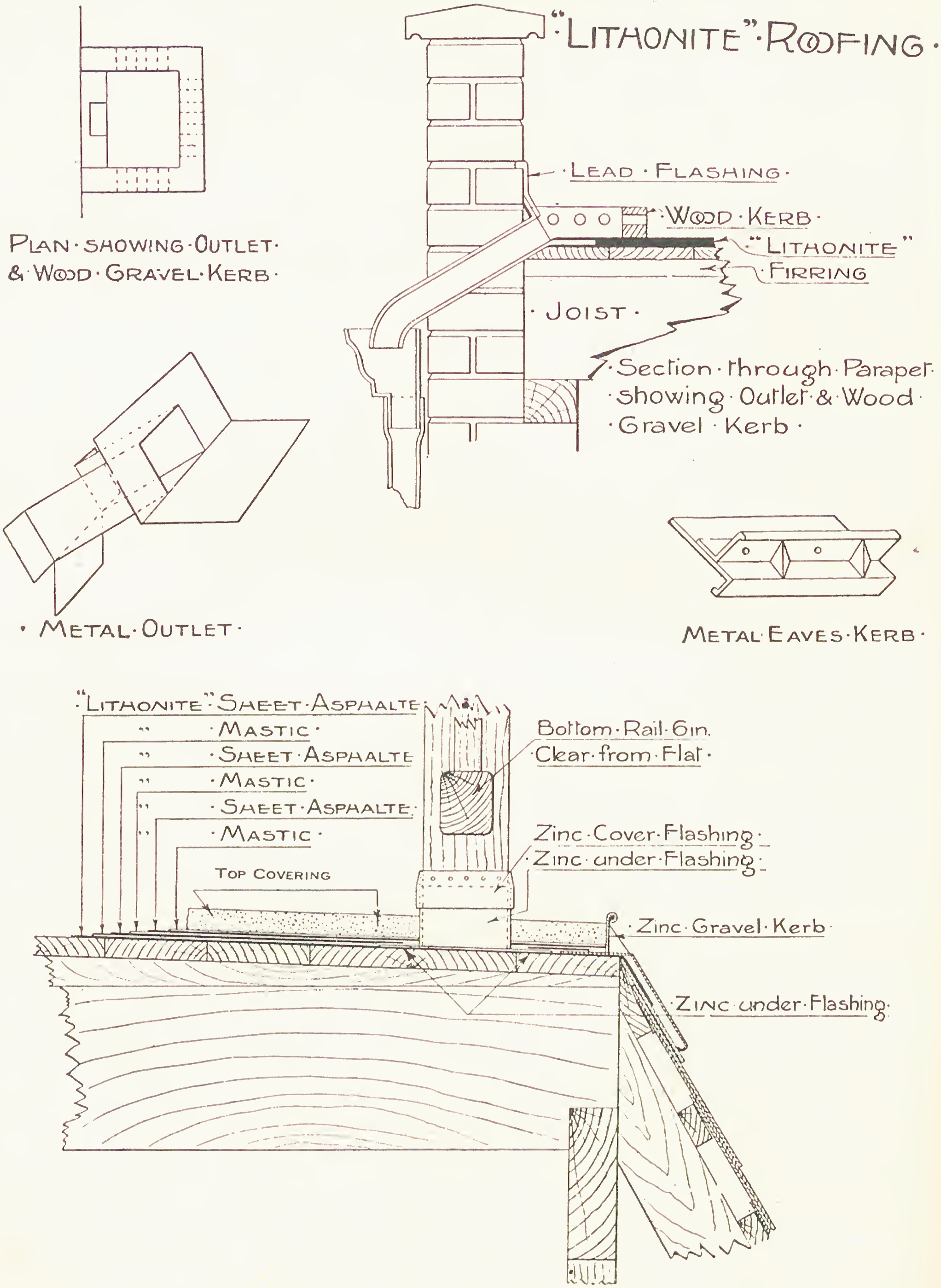


Fig. 265.—Details of "Lithonite" roofing

When finishing a roof for covering with this preparation the builder should roof in with 1-inch boards, tongue and grooved or square jointed. All the joints should be even and if necessary any inequalities planed down, and the nail heads should be punched below the surface. No drips or rolls are required, but the boarding should be laid to a fall of 1 inch in 40 inches. The builder is also required to provide all the necessary wood angle fillets, $4\frac{1}{2} \times 3$ inches, to go round all walls, skylights, and chimneys, to fit but *not* to fix. The gravel kerbs and metal outlets already described are fixed as the work proceeds.

It is also very necessary that, where the underside of the joists supporting the flat are covered in this manner, there should be proper ventilation supplied by air bricks or gratings let into the outside walls and the joist should be perforated with $\frac{3}{4}$-inch holes.

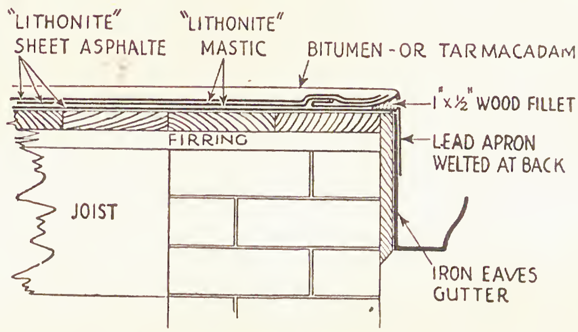


Fig. 266.—" Lithadam " roofing. Eaves.

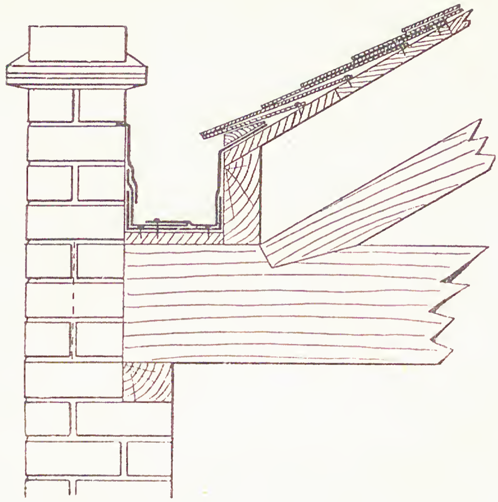
The builder should have a carpenter and a plumber in attendance when this roofing is being laid, and if a sand-and-gravel top covering is to be used the builder should have this on the job ready for use. If a finish of concrete tar paving, or bituminous macadam is decided upon, this will be supplied and laid by the builder, who will also provide and fix the metal drip at the eaves and verge.

Specification for Concrete Flat covered with " Lithonite."—The finish must be smooth and in cement. Where coke-breeze concrete is used a sound surface without dishings is all that is required, laid to a fall in both cases of 1 in 60. All the outlets, metal drips at eaves, metal cover flashings are to be provided by the builder.

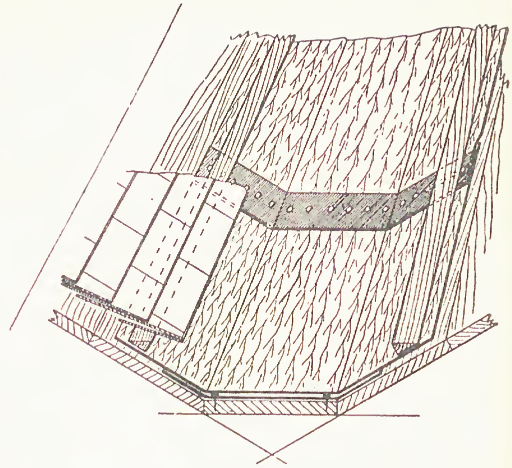
" Lithadam " is a special adaptation of " Lithonite," and " Waterp " is also a similar roofing, but the material employed as sheeting is bitumen impregnated. When laid on flat roofs, either boarded or concrete, the flashing turn-ups and turn-downs can be formed in the roofing, thereby saving the metal flushings; a single—or better, a double—layer of " Waterp " provides an efficient method of repair to a leaky concrete or wood flat roof.

RUBEROID

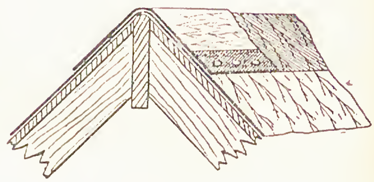
Ruberoid is a fibrous material saturated and thoroughly coated with a compound which renders it proof against the action of the atmosphere and the acids and alkalis therein. It is flexible, light, and non-absorbent, and contains no tar, paper, or rubber, and is manufactured by the Ruberoid



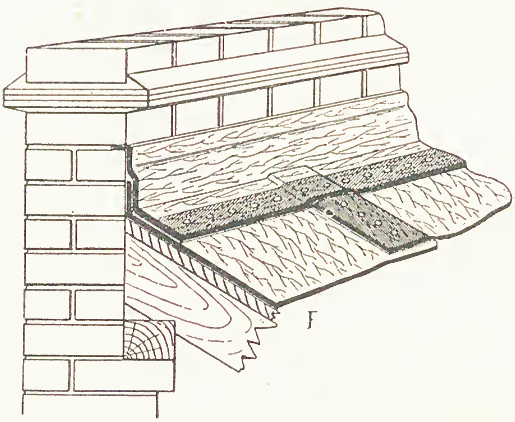
Parapet gutter.



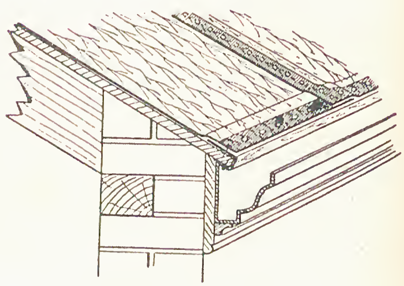
Valley gutter.



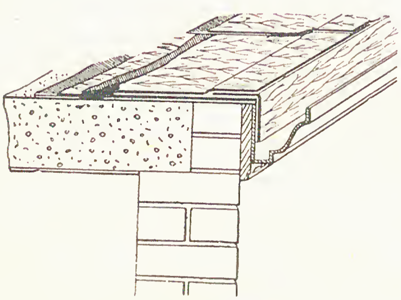
Ridge.



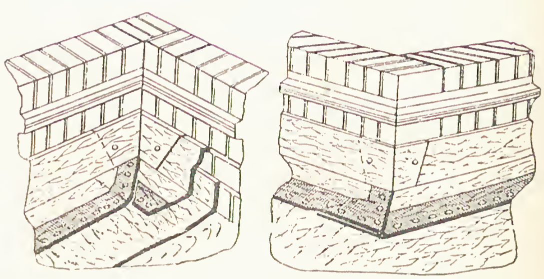
Flushing at parapet.



Eaves of wood roof.



Eaves of concrete flat.

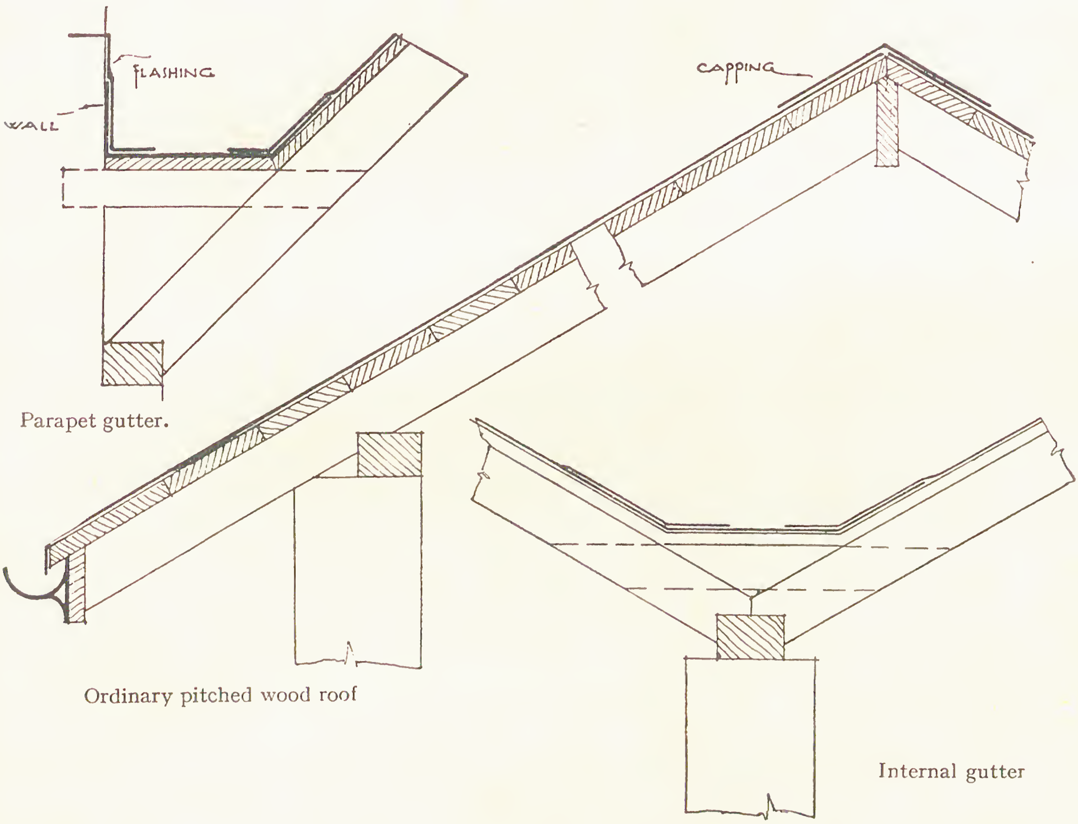


Angles, internal and external.

Fig. 267.—Details of "Waterp" roofing.

Co., Ltd., in three colours, red, green, and grey, and in two finishes, smooth and slate surface. It is supplied in rolls and strip slates.

The standard grey is manufactured in four grades, $\frac{1}{2}$-, 1-, 2-, and 3-ply. The $\frac{1}{2}$-ply is a very light roofing suitable for small-pitched roofs of light portable buildings and outhouses. The 1-ply is suitable for use on all small buildings which are not exposed to severe conditions, and is recommended for small farm buildings, stables, boat-houses, verandahs, and exhibition buildings. The 2-ply is recommended for roofing buildings



Parapet gutter.

Ordinary pitched wood roof

Internal gutter

Fig. 268.—Details of "Ruberoid" roofing.

of the factory class, whereas the 3-ply is reserved for residences, and for buildings exposed to great heat or chemical action and is specially recommended for flat roofs. For giving an enhanced appearance to the building externally the standard red or the slate-surfaced red and green are advised. The strip slates in red or green are suitable for all pitched roofs where a decorative finish is desired.

Constructional Details.—Single-layer Ruberoid is used on boarded roofs of light and semi-permanent buildings over $\frac{3}{4}$-inch tongued and grooved boarding on purlins at distances of 4 feet apart, and the roof boarding must be rigid. It is lapped at the joints 2 inches, jointed with a special cement heated and applied with a brush, and nailed with flat-headed nails supplied with the material at not more than 2 inches apart and 1 inch from the edge of the sheet. If the boarding on the roof is laid horizontally the joints between them should be marked on the roofing material with the chalk line to avoid driving the nails into the joints. All horizantal joints on a slope should be made with the edge of the upper sheet fixed over that of the sheet below. After the nailing is complete

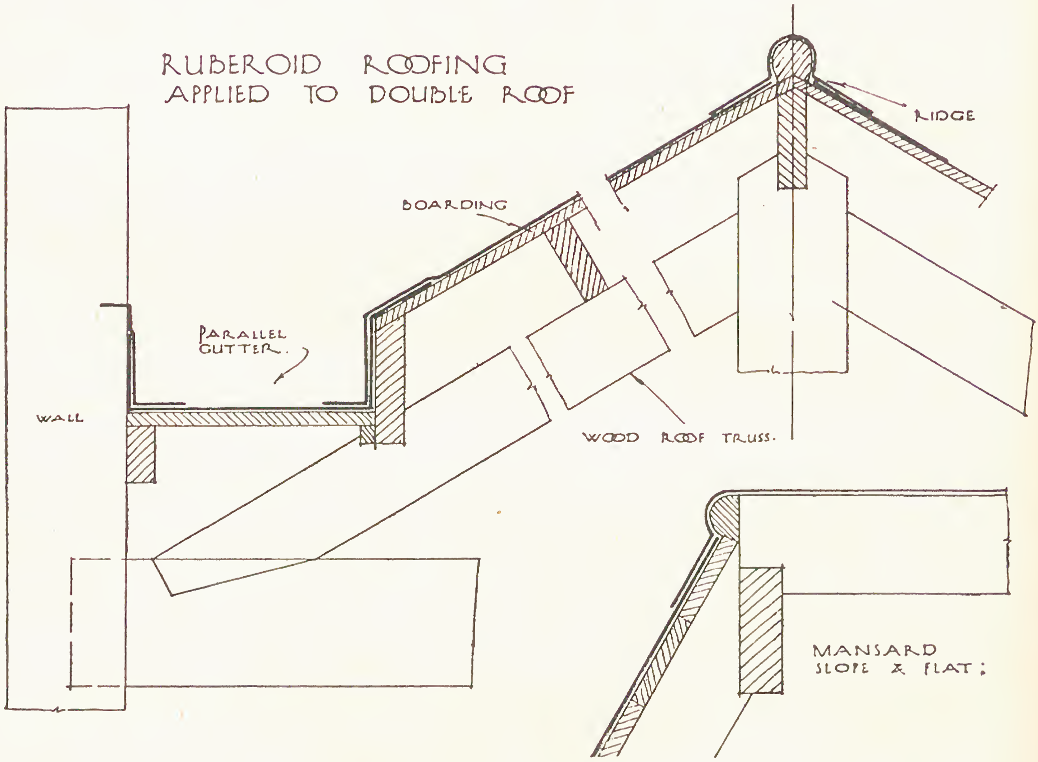


Fig. 269.—Details of "Ruberoid" roofing.

the nail heads and joints should be painted with a band 2 inches wide of the special cement.

Gutters and Valleys.—This work should be done before the main roofing, and two layers of the roofing material should be used in the gutters, the top layer not being nailed at the bottom of the gutter. The double-thicknessed portions are jointed together with Ruberoid cement or mastic. Gutters and flats should fall 2 inches in 10 feet, but no drips are required on flats or in gutters.

Flashings to brick parapets and chimneys, etc., should be formed by raking out a joint 1 inch deep in the brickwork and inserting a strip of the material the length of the wall and of a width sufficient to be tucked into the brickwork joint 1 inch, and in addition to the height of this joint from the roof, 4 inches of the flashing should lie on the flat over the roof covering. The inserted edge is secured into the groove with either lead or wooden wedges and coated with the special cement supplied. The brickwork joint is then pointed in cement mortar.

Internal angles are formed with specially shaped flashings, and the splayed edge of the upper flashing is nailed down over the one below. External angles in flashings have also specially cut shapes, the splayed

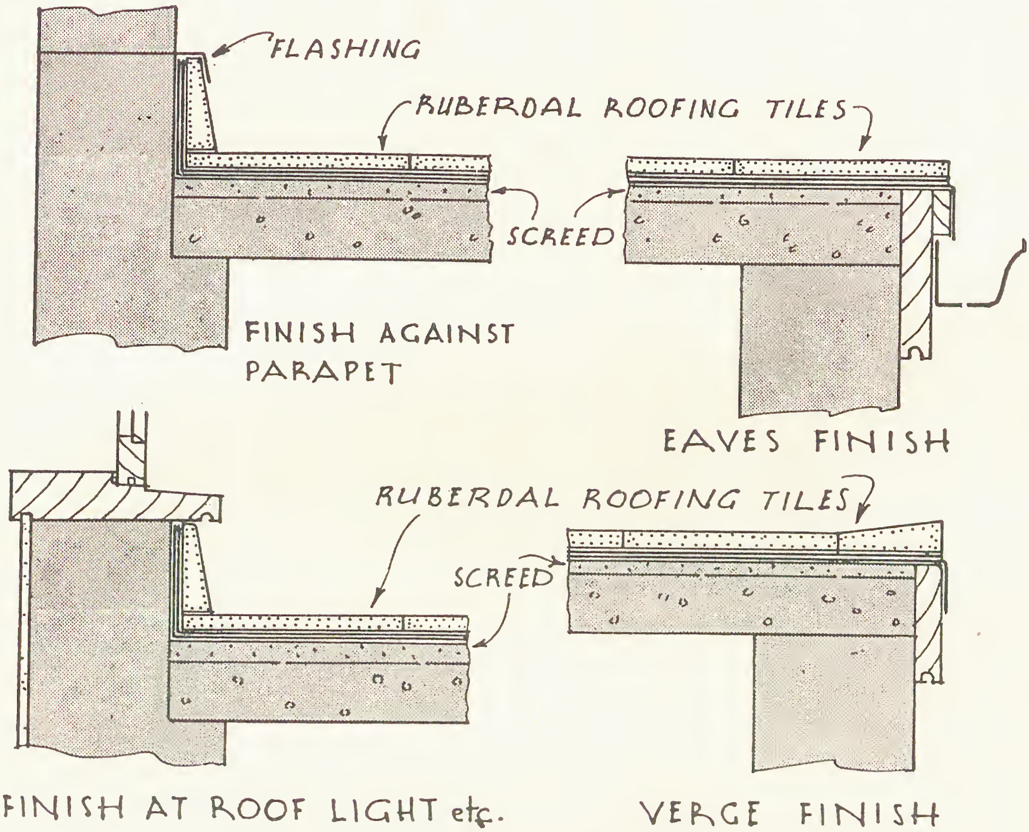


Fig. 270.—" Ruberdal " roofing

strip being fixed over the square-cut strip and nailed, the splay being in this instance outwards towards the bottom instead of inwards as with the re-entrant angle.

Step Flashings to sides of chimneys on the slope of a pitched roof should be turned up the wall at least 3 inches, and are cut out of triangular strips of roofing, wedged into the brickwork joint and turned down and on to the roofing and cemented thereto. The work to these flashings should be started at the eaves, so that each higher flashing laps over the one below it. Coat the nail head and point joints in the brickwork.

Eaves and Verges are finished by nailing the roofing to the edge of the roof boarding, so that it turns down into the rainwater gutter.

Ridge and Hips are formed with an 8-inch-wide strip of roofing bent over to lie 4 inches on either side and cemented and nailed.

Outlets should be lined with lead or zinc, and the roofing material turned down into the cesspools and nailed and cemented to the sides.

In cold weather this roofing should be warmed before being bent to shapes by passing a blow-lamp back and forth over the part at which the bend is required ; but this must not be overdone.

Ruberoid Strip Slates are fixed to roofs having a fall of not less than 6 inches to the foot and on $\frac{3}{4}$-inch close boarding, any upstanding edges of which have been planed flush and all nails punched in.

The operation of fixing is the following. First fit a strip of slate-surfaced Ruberoid $8\frac{1}{2}$ inches wide to eaves and verges, nailing it to the edge of the roof boarding with $\frac{3}{4}$-inch copper clout nails, and dress this down $\frac{1}{2}$ inch to 1 inch below the bottom edge of the boarding. The first course of strip slates should then be nailed parallel to the eaves, each slate having its lower edge flush with the eaves, and the strips being in close contact side by side. The first course should be started at one end with a strip composed of four slates, and the next course above with one composed of $1\frac{1}{2}$ slates, and so continued in alternating courses. The centre of the butt of each cut tile shape should lie over the cut-outs on the slates beneath. Each strip should be secured with $\frac{3}{4}$-inch galvanised clout nails driven in $\frac{1}{2}$-inch above each cut-out, so that the nail heads are covered by the butt of roofing $4\frac{1}{2}$ inches down each sloping face and over the ridge or hip, and by nailing its bottom edges with copper clout nails every 2 inches.

Do not nail anywhere except as advised, or a leaky roof may result.

Ruberoid on Concrete is fixed by bedding in the special compound provided by the manufacturers. This is supplied in solid form and requires heating in a cauldron and used hot when it is liquid. Joints are lapped 2 inches, and are also cemented with the compound, *no* nailing being required.

On Boarded Roofs the built-up roofing requires the first layer to be nailed with $\frac{3}{4}$-inch clout nails and the lengths lapped 2 inches. The layers above are bedded down with the compound, the joints of the various layers being staggered.

For Flat Roofs two or more layers are recommended, and these may, if desired, be finished with a coating of compound and a covering of sand or shingle.

It is advisable to work this roofing 14 days before using, to permit it to expand, and it will be found to effect a saving of time if the rolls are then cut into the lengths required. The outside of the roll should be laid downwards, *i.e.* on the boarding. If the boarding is springy, better results are to be obtained by fixing the roofing with its length at right

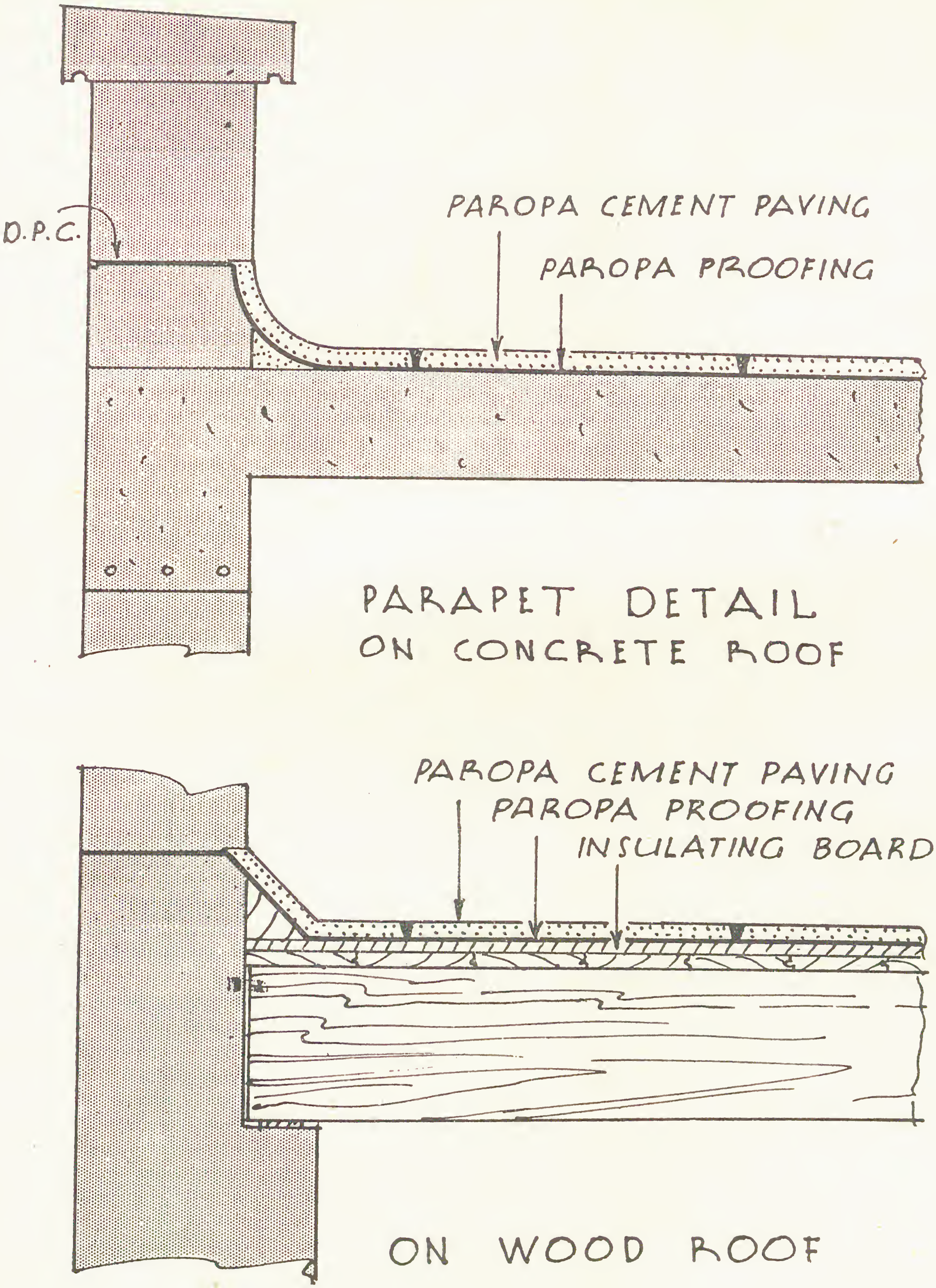


Fig. 271.—" Paropa " roofing.

angles to the boards. This roofing should *not* be laid in a continuous strip up one slope, over the ridge, and down the other slope.

VULCANITE ROOFING

This is another speciality roofing, suitable for the same purpose as that last described, and is of a bituminous, horn-like, and elastic substance, which, whilst retaining its elasticity, becomes in the course of time of metallic hardness. It is impervious to water, and resists the destructive action of the atmosphere, and it affords a very satisfactory surface for roof gardens and similar purposes. It is claimed for this roofing that it is incombustible and fire-resistant, and it can be laid on wood or concrete.

The specification given by the manufacturers, Messrs. Vulcanite, Ltd., for preparing a wood roof to receive this roofing is as follows:

"The roof to be 1-inch boarding nailed down to wooden joists, nails driven well home and edges even. If the roof is to be left unceiled tongued and grooved boarding should be employed.

"The surface to be a continuous and even surface without drips or rolls.

"A fall of 1 in 40 to carry off the rainwater.

"The contractor to supply wood triangular fillet, $4\frac{1}{2} \times 3$ inches, to go all along parapet or other walls, skylights, chimney stacks, roof entrances, etc., but not to fix the fillet till the sub-contractors' men are on the works.

"When draining to eaves gutter, the boarding to be flush with fascia. Where there is no eaves gutter the rainwater can be carried through the parapet wall by means of lead-lined outlet. Where wood newels occur on the roof the bottom rail must be quite 6 inches in the clear from flat.

"Unless provided for in our estimate, outlets must be supplied by the builder, who is to have a plumber on the works on our arrival to make them to our instructions.

"When draining to eaves or any other gutter, it is necessary to use either a zinc or copper gravel kerb, which can be supplied by the sub-contractors.

"All gutters, other than eaves gutters, to be 4 inches deep at shallow end.

"All eaves gutters should be in position before sub-contractors are on the works and all mansards ready slated.

"It is necessary to cover the vulcanite with $\frac{3}{4}$-inch loamy sand and $1\frac{1}{4}$ inches of shingle, which the general contractor is to supply and have on site before the sub-contractors commence work. Breeze, cement concrete, tiles set in cement, or tar-macadam may be used instead of sand and shingle.

"The sand and shingle is used to make the roofing fireproof from the outside, to protect it from the direct rays of the sun, and from wear and tear, also to provide an even temperature to rooms immediately below roofs. The London County Council and the Fire Assurance Companies also require it.

"Immediately upon completion of the work the general contractor is to flash with lead or zinc the $4\frac{1}{2} \times 3$-inch wood fillet previously mentioned, which is covered with vulcanite, and this flashing is to be within $\frac{1}{4}$ inch of the sand and gravel, or finished surface.

"When tar-macadam or concrete is employed as a covering to the

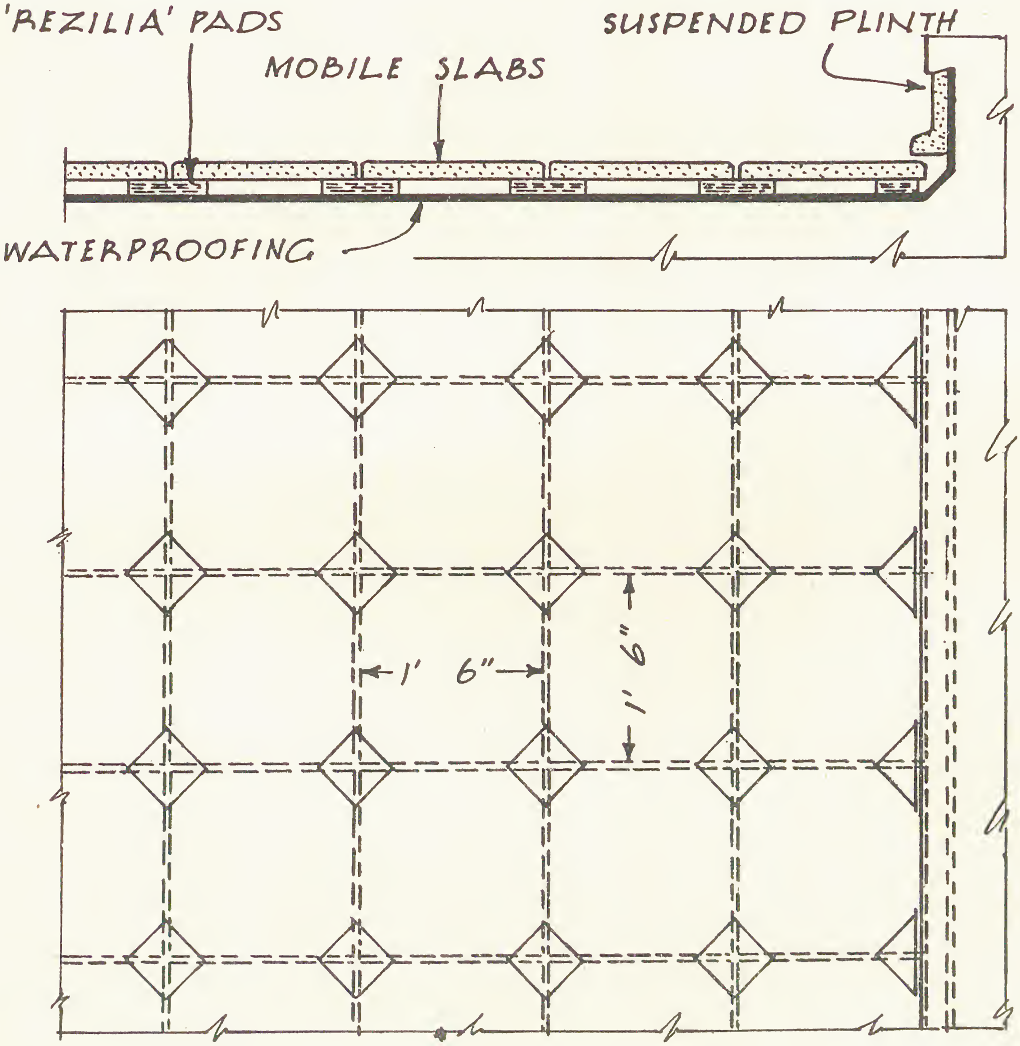


Fig. 272.—Callender's air-insulated flat-roof covering

vulcanite, and it is continued from the flat up to the top of the fillet, the lead cover flashing need be only sufficiently wide to cap the top of the fillet and dressed down on to it $1\frac{1}{2}$ inches.

"Where the underside of joists are lath and plastered, two or three air-bricks should be used between the joists, the intervening joists to have holes or perforations through them so as to provide ventilation.

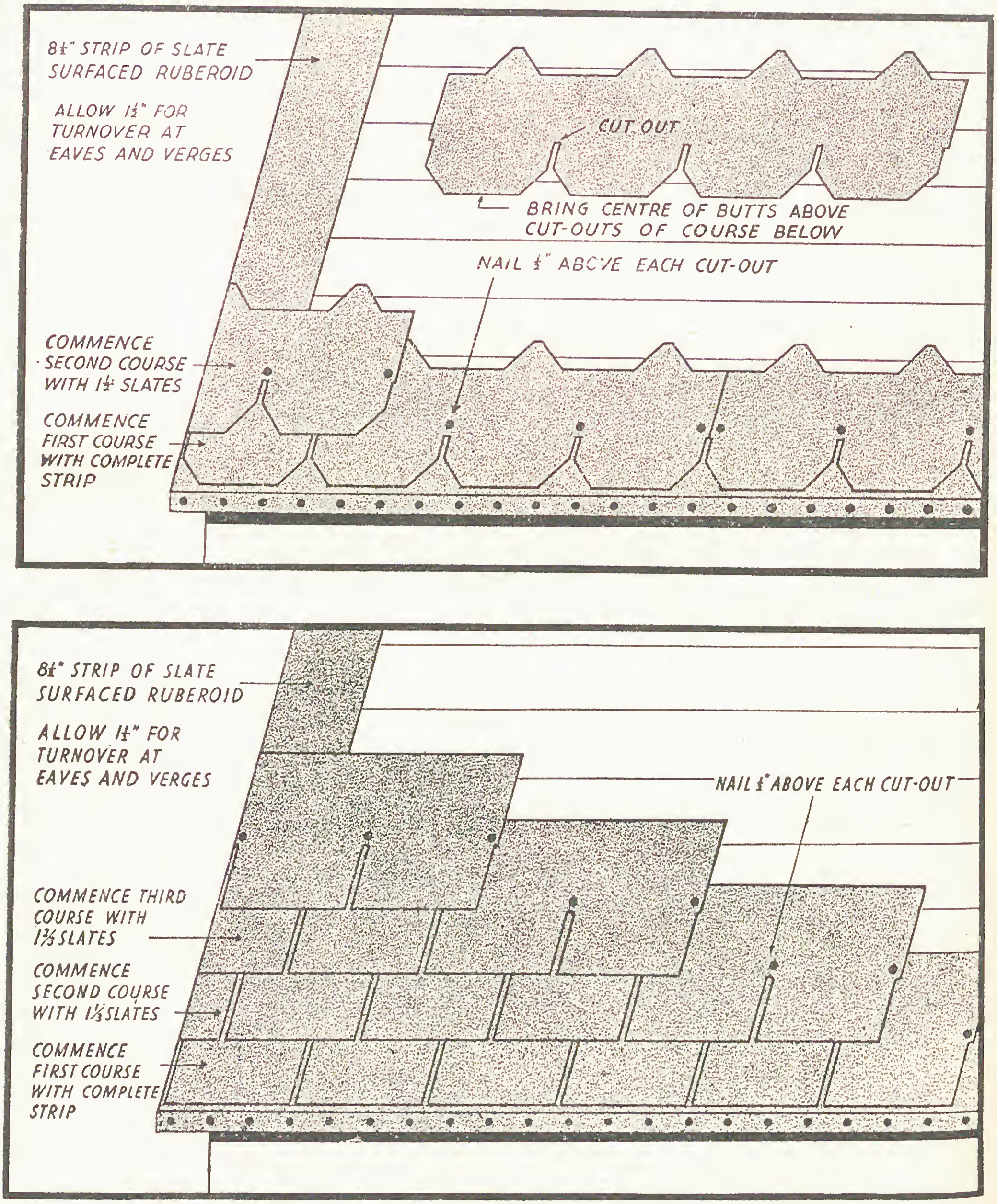


Fig. 273.—(Top) Ruberoid diagonal slates; (bottom) Ruberoid twin-butt slates.

"It is necessary, therefore, when asking for an estimate, to say if the roof is of wooden or concrete construction and to give all particulars as to parapet or surrounding walls, eaves, verge, wooden newels, iron railings, etc., and to say if the flashing is to be included in the estimate or not, and if so, whether lead or zinc or copper."

Constructional Details.—*Fillets and Cover Flashings to Flat Roofs* are formed over a wood fillet into the angle $4\frac{1}{2} \times 3$ inches, the roofing being turned up over this and butted against the vertical brickwork. A 5-pound lead cover flashing is let into a raked-out brickwork joint and dressed down over the roofing. But as this method is liable to leakage caused by capillary attraction, the manufacturers advise the following improved method. In this a patent flashing is used which, by reason of its formation, a capillary trap is effected and in place of the usual lead wedges in the brick joint a special compound wedge termed the Grip-flash wedge is used. This is made of malleable iron in three pieces held together with an expanding metal clip, and when driven in by the simple mechanical action of driving home the protruding tongues or wedge it thus provides a sure and certain fixing for the flashing in the joint. The upper and lower plates of this wedge, being serrated, grip the brick faces.

Eaves and Verges are formed with a patent metal kerb which permits of a quick and uninterrupted flow of water draining from the flat into the gutter and prevents the water from getting back into the boarding and joists at the joints.

Concrete Roofs should be laid to a fall of 1 in 60. When the concrete is of coke breeze, a sound surface must be provided, but it need not be floated. Where ballast or other concrete of large aggregate is used, all unevenness must be levelled off with cement and sand with a straightedge.

Against vertical faces the $4\frac{1}{2} \times 3$-inch angle fillet is formed in cement, and the lead or zinc flashing is dressed down over the covering of tar-macadam laid over the roofing preparation.

When the vulcanite is to be covered with 2 inches of gravel, proper gravel kerbs must be provided at outlets or eaves to retain the gravel.

Where a gravel kerb is not used, a lead under-flashing should be fixed at the eaves, mansard, or verge to form a drip having a $1\frac{1}{2} \times 3$-inch triangular wood fillet inside, or alternatively a special zinc or copper kerb, provided by the manufacturers, may be used. All flashings and outlets may be provided either by the builder or by the manufacturers as arranged.

Where it is desired to use the roof as a garden, 2 inches of loamy gravel gives the best finish, though cement concrete, tiles set in cement, or tar-macadam may be used.

CHAPTER 17

METAL ROOFING AND ROOF GLAZING

LEAD ROOFING

LEAD is used in sheets to cover flat and pitched roofs, also to line gutters and to form flashings at intersections of roofs with vertical erections such as chimneys, parapet walls, and skylights. It is also used on domes and turrets. Lead, however, owing to its characteristic of creeping, due to the effect of changes of atmospheric temperatures, is not an entirely satisfactory material for covering steep-pitched roofs ; and even on flats it is most important that it should have one end free to permit of expansion and contraction without buckling.

Characteristics and Properties.—Pure lead is a lustrous bluish metal, soft and plastic, but having no elasticity. Exposed to the air it tarnishes, due to the formation of a film of lead carbonate over the surface which is termed " the patina." It melts at a temperature just about 300° C. and boils at between 1,450° and 1,600° C. When carbon dioxide is present, as it is to a large degree in most city atmospheres, lead corrodes continuously until it becomes decayed and requires renewal.

Lead is found in lead ores, "*galena*" being the chief, and has a world-wide distribution. The principal lead mines in England are in Derbyshire, and perhaps the oldest are in the Mendip Hills in Somerset, where old Roman lead mines are still to be seen. Lead was known to the ancients and is mentioned in the Old Testament.

Extraction.—The lead is obtained from the ore by roasting it, in either the reverberatory furnace, the ore-hearth, or the blast furnace, the last being the most usual method ; but the lead produced by the two first methods is of a higher grade than that produced in the blast furnaces.

A modern blast furnace is about 24 feet in height from furnace floor to feed floor and of oblong horizontal section. An inclined channel runs through the side wall, beginning near the bottom of the crucible, and ending at the top of the hearth, where it is enlarged into a basin. The crucible and channel remain filled with lead whilst the furnace is working, and the lead, reduced to the metallic state, in collecting in the crucible overflows along the channel into the basin, the impurities which float on the top of the lead in the crucible being drawn off into slag-pots.

Lead Flats.—The lead used for covering flats is in rolled sheets either as *cast lead*, 16 feet to 18 feet in length and 6 feet wide, or as *milled lead*, when the sheets are from 25 feet to 30 feet long and from 6 feet to $7\frac{1}{2}$ feet wide. Cast lead is thicker and heavier than milled lead, and has a harder surface, but is liable to flaws and sand holes. Milled lead is more uniform in thickness and cast lead is now rarely used for roofing.

Lead used in building is specified by its weight in pounds per foot super. That used for flats and gutters is generally required to be from 7 pounds to 8 pounds; for hips and ridges, 6 pounds to 7 pounds; and for aprons and flashings, 5 pounds.

The following table (Rivingtons) gives the thickness of sheet lead for different weights per *square* foot.

TABLE GIVING WEIGHT AND THICKNESS OF SHEET LEAD

Weight in pounds per superficial foot.	Thickness in inches.	Weight in pounds per superficial foot.	Thickness in inches.
1	0·017	7	0·118
2	0·034	8	0·135
3	0·051	9	0·152
4	0·068	10	0·169
5	0·085	11	0·186
6	0·101	12	0·203

The lead is laid on roof boarding, which must be rigid to prevent cracking in the lead, and the boards should be laid in the direction of the fall, so that any curling tendency in the boards may not cause ridges at right angles to the direction of the fall. Also the sheets of lead should be laid in the direction of the fall, which should not be less than 1 inch in 6 feet, though it may be required by conditions to make this fall as much as 3 inches in 10 feet. Over the boarding in best work there is laid an asphalted felt, butt jointed, and not lapped at its edges, and if possible the joints in the flat should come under rolls.

Jointing the Sheets.—Rolls are used to joint the sheets in the direction of the fall, and *drips* for those joints at right angles to the fall. The purpose of the roll is mainly to overcome the difficulty already mentioned, that the sheets must not be nailed on all sides, and at the same time the division of a flat into compartments prevents the rainwater from spreading with a consequent tendency to lie in any depressions.

Rolls are formed either solid or hollow: the *Solid Roll* consists of a batten rounded to a 2-inch diameter and cut square at the base to fit down on to the boarding, or if felt is used, on to the butted joint of the felt. The lead is dressed up to and over the roll, the edges of adjacent sheets of lead being lapped one over the other, the uppermost one being that in the direction from which the prevalent wind blows, and is called the *Overcloak*. The other edge, the *Undercloak*, is the first laid, and should not extend farther than to the crown of the roll. The overcloak

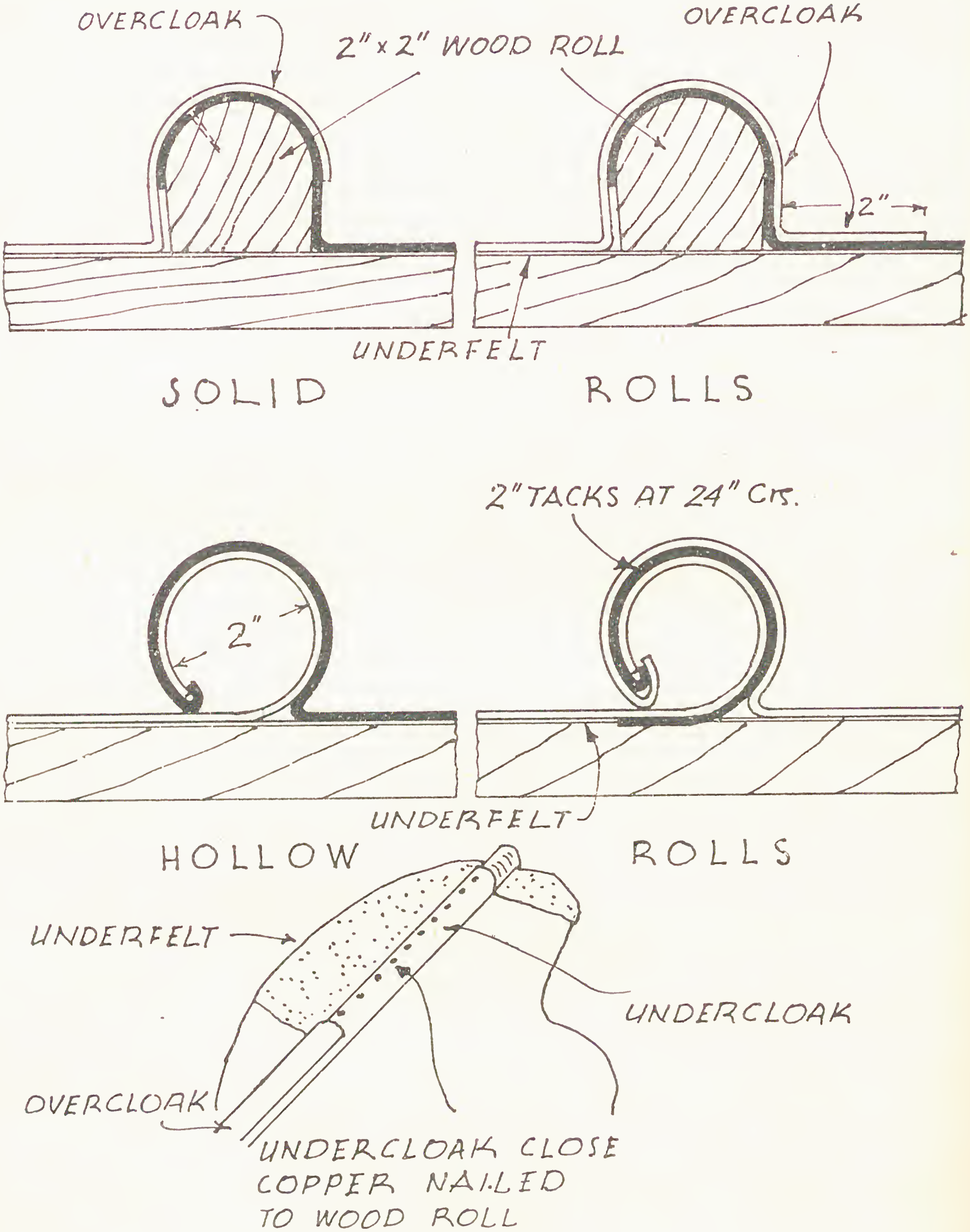


Fig. 274.—Lead rolls.

should be extended three parts of the way round the roll so as to leave at least $\frac{1}{2}$-inch space between its edge and the surface on the lead on the flat. Dressing lead for overcloaks right round the roll and on to the flat is condemned by some experts as it may cause the lead to crack in excessively hot weather, owing to its freedom of movement being unduly restricted.

Hollow Rolls are formed by placing the sheets so that a lap of about 4 inches is given and turning the edges of both sheets up together at right angles to the surface of the flat. In between the turned-up edges at every 2-foot distance apart 6-inch lead strips by 2 inches wide are nailed to the boarding of the flat, and these are turned down to one side with

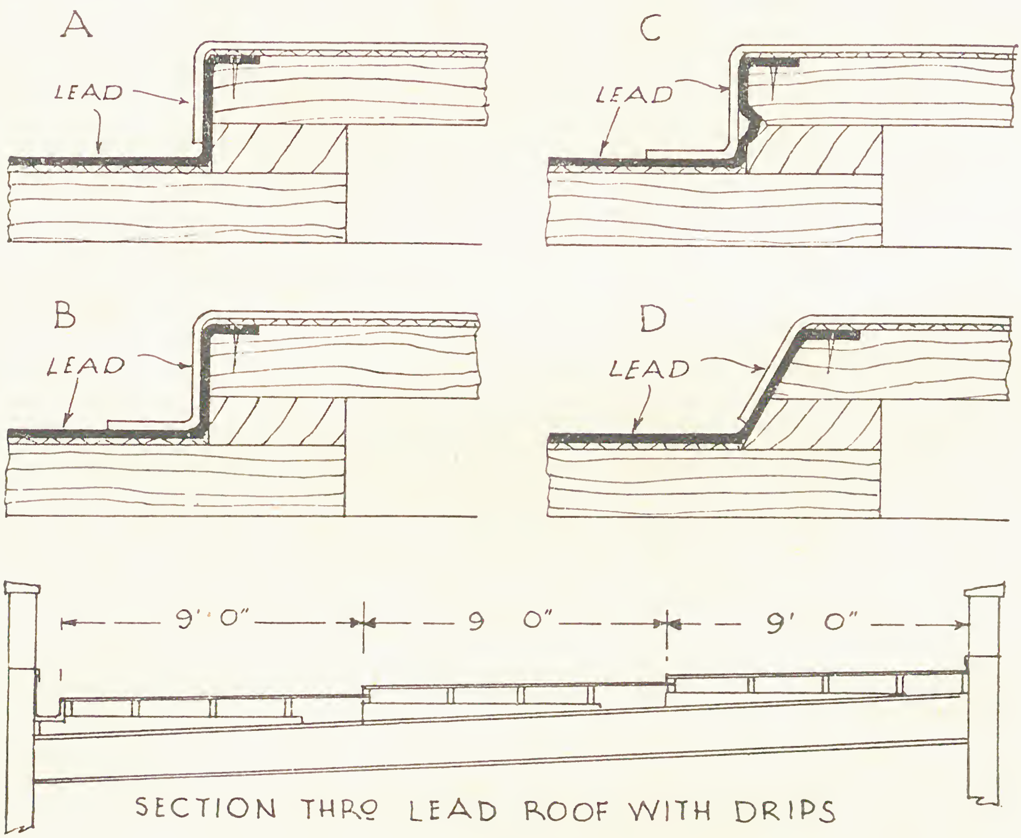


Fig. 275.—Lead drip joints.

the edge of one sheet to afford a clip to that edge over the upright edge of the adjacent sheet. These lead strips are termed *Tingles*.

The turned-up edges are then dressed to one side in the form of a roll having an internal hollow of a diameter of about 2 inches.

Ends.—The ends of rolls are bevelled and rounded and " bossed."

Nosings.—Where a flat is formed on the top of a pitched roof the angle formed by the junction of the flat and the slope is protected from the weather by a flashing of lead, termed an apron, jointed to the lead sheet on the flat by what is really a flat roll, dressed down flush with the surface of the flat, and against the edge of the boarding to the flat. The flashing should be first dressed up into the angle made by the top course of slates on the sloping roof and the edge of the flat boarding, the top edge of the flashing lining with the top edge of the boarding. Over this is nailed the flat rounded wood roll, over which in turn is dressed the edge of the lead sheet on the flat.

Alternatively hollow nosings which may be "bottled," *i.e.* rounded or dressed flat, are formed in a similar manner to hollow rolls.

Drips are steps formed in making joints in sheets of lead in the direction of right angles to the current, as in a lead gutter. They should be from 2 inches deep and at intervals of 10 feet. There are three kinds of drip joints most generally used, all being forms of dressing the edge of the sheet on the higher level down over the upturned edge of the sheet on the lower level.

The Bottle-nosed Drip.—In this joint the boarding is projected 1 inch beyond the upper bearer, and the lead is turned down over this projection and the edge of the lower sheet, which is dressed up tight into the angle to finish against the underside of the projected boarding.

Tacked Drips are used in exposed positions, where the wind would be liable to rip up the turned-down edge of the upper sheet. The principle is the same as that employed in forming rolls; the lead tacks, being similar to tingles, are fixed at 18 inches apart to the boarding beyond the edge of the lower sheet of lead and turned up at their bottom ends to secure the turned-down edge of the upper sheet.

Hollow Drips are also used in exposed positions, and are formed by turning the top edge of the lower sheet away from the bearer and bending it downwards to form a hollow tube. Over, and without disturbing the hollow, the edge of the upper sheet is dressed round and against the vertical face of the lower sheet dressed against the bearer.

A Welt is really a roll that is dressed tight and flattened. It is frequently used on nosings to the edges of flats which have a sloping roof below, and where it is desired to secure the flashing over the top course of slates or tiles on the sloping roof to the leadwork covering the flat. The form of joint then used between the flat covering lead and the flashing is the welt. It is formed by leaving 4 inches or so of projection beyond the kerb or nosing of the flat and then fixing the flashing so that 2 inches of it projects beyond the point at which it is fixed to the kerb. The projecting edge of the upper sheet is then folded round and under the projecting edge of the flashing, and then both edges are folded again and dressed back against the edge of the flat roof boarding, the top edge being rounded. In very exposed situations the welted nosing is given additional security by the insertion of tingles in the manner already described.

In jointing long and narrow sheets of lead, such as are used for hips, ridges, flashings, one sheet is dressed down over the other by simply being

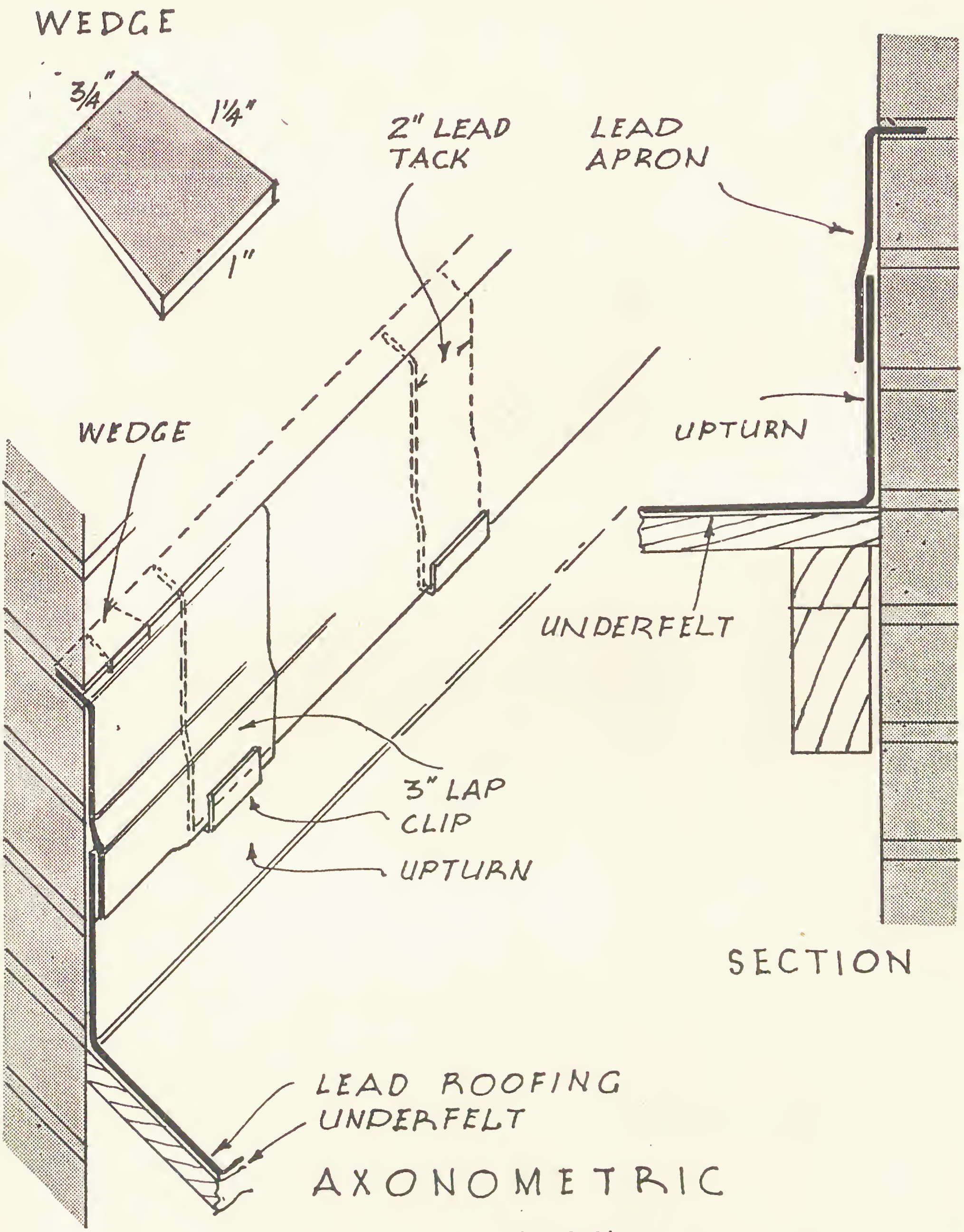


Fig. 276.—Lead straight flashing.

beaten down flat with a lap of about 6 inches. This is termed a *Lapped Joint.*

Dressing Lead.—To speak of "laying" lead on roofs is to give a wrong impression, much as if there were no more involved in the operation than in laying sheets of building paper. The lead, however, as has been explained, comes to the job in rolls, and lead, though malleable, requires considerable work first in unrolling and next in getting it to fit tightly into the positions in which it is required to lie. After this there is, in addition, the work of forming the joints and of dressing the lead into angles and round corners and projections. All this is slow work, and requires considerable hammering and the aid of certain tools and wooden shapes.

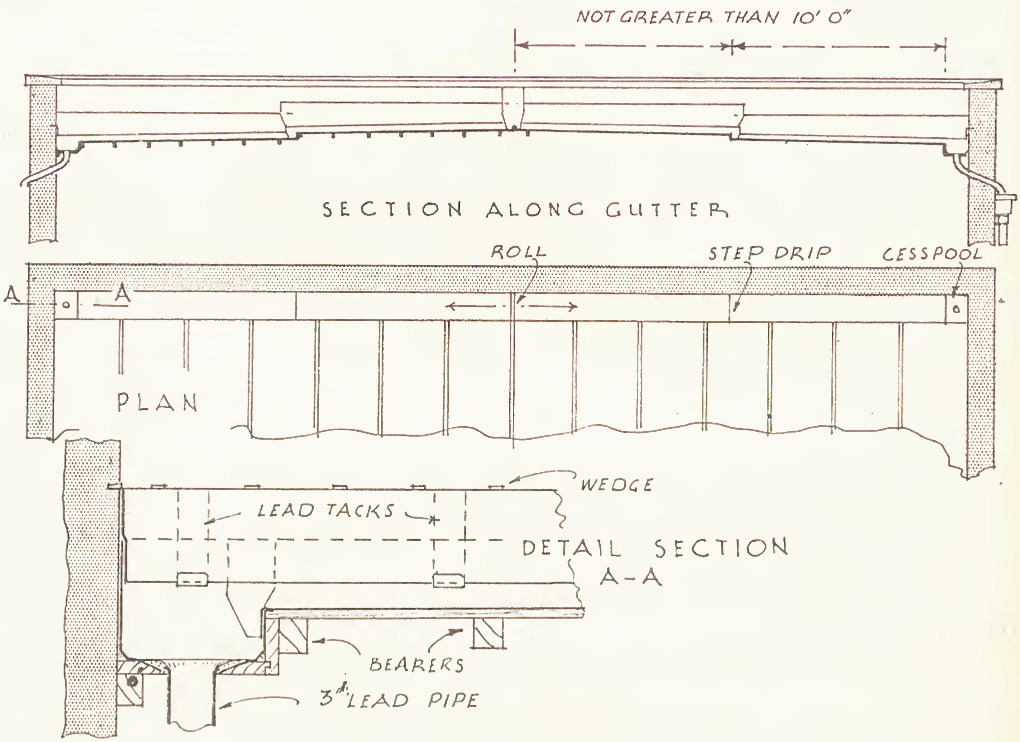


Fig. 277.—Lead parallel gutter against boundary or parapet wall.

Tools Used.—For Marking and Cutting out the sizes required from the rolls a chalked line is used, held at both ends and snapped along the line which it is desired to cut. In cutting the work requires two men, and a knife is used having a long handle, which is pressed down with the shoulder whilst the assistant pulls on a cord attached to a hole near the blade end of the knife.

The Laying Tools are mainly bossing sticks and dressers, used either as mallets or in conjunction with mallets.

Hammers having a wedge at one end of the head and a circular flat at the other are used for working angles and preparing seams. The bossing sticks are used mostly for working internal corners and the mallet is used directly on the lead for bossing or rounding external corners and ends.

In Dressing the Undercloak over a wood roll its edge is first splayed off with a rasp or a shave hook, and it is then nailed to the roll after it has been dressed down flat with copper nails 6 inches apart.

The Overcloak is formed by laying the next sheet in position with its edge upturned at right angles, known as the *Upstand.* This upstand must fit against the roll and be dressed into the angle formed by the roll and the flat by the use of a dresser and mallet. The upstand is then bent downward over the roll to form the overcloak by the use of a flat board until the top edge of the overcloak touches the surface of the lead on the other

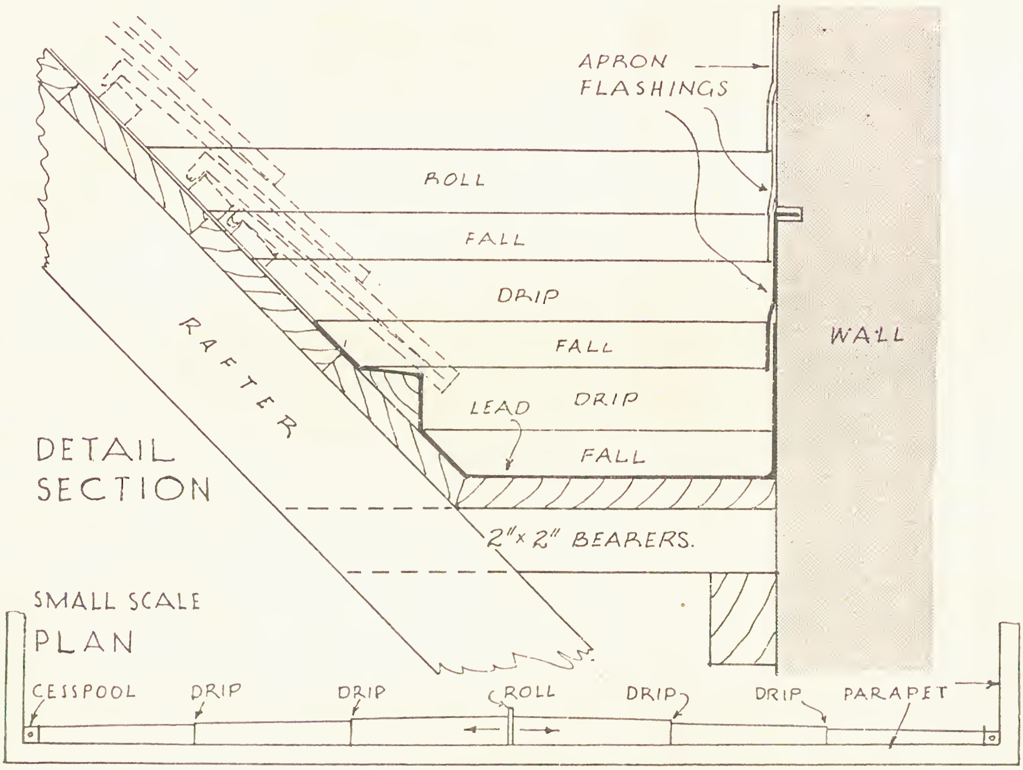


Fig. 278.—Lead tapering gutter.

side of the roll. This overcloak is then bent into the angle of the roll and roof by means of a length of wood roll and then dressed lightly with the rounded side of the dresser. This work requires considerable practice, as indeed does all plumbing work, as it is patience rather than force that is required—a number of repeated blows being far more what is required than a few heavy ones which tend to stress the lead at certain points, whereas what is desired is that the lead should be induced to take on a new shape and to lie in that shape without strain.

A roll is finished against a vertical face by having the overcloak turned up against that face to form a kind of flashing which requires special slots cutting in the edge of the lead. The free ends of rolls have the ends of the undercloak worked over the end of the roll with its edge cut at 70°, and the overcloak is worked downwards and outwards over this, which operation is termed bossing.

Gutters sheeted in lead are either V-shaped or box squared gutters.

Where a *Box Gutter* comes between two sloping roofs, the sides of the gutter are formed of two beams with bearers between to carry the bottom of the gutter. The bearers are covered with boarding, but the lead is laid straight next the sides of the beams. The lead lining to the gutter when shallow is in one sheet, which is first bent to the required size to fit the box gutter approximately, and then dressed into the angles. The top edges are dressed down along the sloping roof at the sides finishing over feather-edge tilting fillets.

Gutters over 9 inches deep require cover flashings at the tops of the sides, *i.e.* narrow strips turned down over the upstanding sides of the gutter lining and along the roof or into brickwork if the gutter comes against a vertical wall.

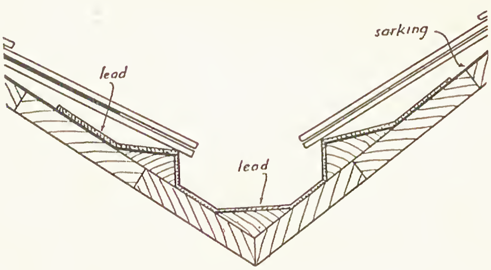


Fig. 279.—A small lead valley.

"*V*" *Gutters* should average 9 inches in width and be formed of one sheet of lead dressed down on to the boarding over the roof bearers and up the slopes at the sides 3 inches, then over a tilting fillet $2\frac{1}{2}$ inches wide, and then a further 3 inches up the roof boarding above the fillet.

Cornice Gutters.—Where a cornice overhangs a footway it is required to be supplied with a gutter to prevent the rainwater from falling. Such a gutter in a widely projecting cornice is formed of two sheets of lead—one being dressed round the square gutter and over the tilting fillet on the roof, and the other being laid on the upper surface of the cornice, which should be weathered inwards towards the gutter and turned down 1 inch below the vertical face of the top member of the cornice to form a drip.

Where no gutter is required, the lead is laid over the top of the cornice sloped outwards and up against the wall face, and covered with an apron let into the brickwork.

Soldered Dots.—On stone cornices and stone cappings to parapet walls, where it is desired to protect the stone work from rainwater, it is covered with lead, and a shallow sinking is formed against the bottom of the vertical face to form a trough. The lead is dressed over the flat of the cornice and into this sinking and up the vertical face; and a cover flashing is let into a chase, cut in the vertical face and down over the upturned face of the lead. To fix the lead down securely on to the top of the stone cornice a dove-tailed hole is cut into the stone and filled with lead, and into this lead-lined screws are driven.

Burning in.—This is a similar operation, and consists of pouring molten lead into a groove, such as that mentioned above to secure the flashing over an upturned surface.

Cesspool.—At the ends, or at other convenient points in gutters, *cesspools* are formed, into which the gutters discharge, and these are also lead lined. This lining for small cesspools is bossed out of one sheet of lead, but for cesspools over 6 inches deep the sides are formed of a separate sheet and the bottom of another.

Flashings.—Where roofs are intersected by vertical erections, such as chimneys or parapet walls, an awkward junction is formed which, unless protected by some continuous and impervious material, would allow the rainwater to penetrate the roof. To prevent this narrow strips of lead are placed in the angles so formed. This is termed a *Flashing*. Let into a joint in the brickwork and turned down over the upstanding end of the flashing is another strip of lead, which is called the *Hanging* or *Cover Flashing*.

Stepped Cover Flashings are strips used at the sloping sides of the vertical wall, having their top edges cut into steps to form short horizontal lengths to fit into the brickwork joints.

Aprons are the flashings used along the face ot a chimney and the sloping roof below it or under the sill of a dormer window ; and a single-strip flashing made to lie 6 inches on the roof slope is called an *Apron Flashing*.

The upper piece of lead is wedged into the raked-out joint with lead wedges and the joint pointed in cement. The raked-out joint is termed a *Raglet*.

Thus at the intersection of a sloping roof by a chimney, on the upper side of the slope, a lead gutter is formed, having a hanging flashing to cover its upstanding part and let into a brickwork joint 6 inches above. On the lower side of the slope a single strip 15 inches wide is laid 8 inches on the slope of the roof and 6 inches against the vertical face of the chimney and the remainder turned into the raglet. This is termed a *Chimney Apron*. At the sides are the *Side Flashings*, which may be either *Raking Flashings* or *Stepped Flashings*, or a third alternative, *Cover Flashings in Separate Pieces*.

Soakers are small pieces of lead used instead of stepped flashings, and they are worked in between the slate or tile courses, each piece being about 4 inches longer than the gauge of the slating or tiling. Six inches is turned up against the wall and 8 inches on the roof. The soaker is covered by an apron or cover flashing.

Ridges and Hips.—Wood rolls cut pear-shaped are used in forming ridges and hips in lead. The best and most weathertight formation for these is to first lay a strip about 18 inches wide over the hip rafter or ridge and dress it down on to the roof. The roll is then screwed down over this, and over the roll another strip about the same width is laid and dressed into the angles the roof makes with the roll, and down on to the face of the under strip. This under strip will be found to project beyond the edges of the upper strip, so that these projecting edges may be then turned upwards to clip the edges of the upper strip.

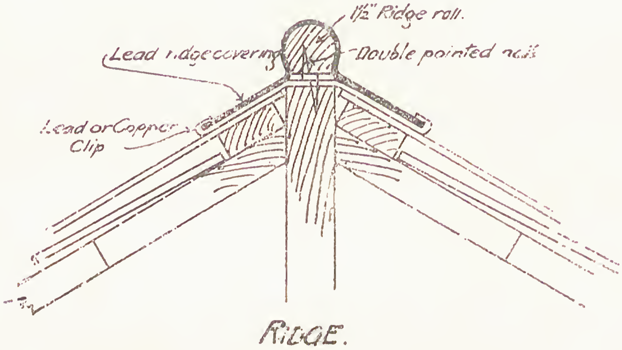


Fig. 280.

A cheaper form of lead covering is to first fix the wood roll and then to dress the lead over it and down on to the roof covering at each side, tacks being inserted at 30-inch distances to secure these edges against being lifted by the wind.

Secret Tacks are used to give additional security. These are strips of lead 5 inches wide and long enough to span the roll, and when cut they are soldered to the underside of the covering strip through a slot cut in their centres.

Hip Soakers.—Hips are also formed of 4-pound lead soakers under mitred slates or tiles when no special-made hip tile is used; special gutters are sometimes formed, in more expensive work, over the hip rafter and under the roof covering.

The best modern practice is described in detail in the publications of the Lead Industries Development Council, Rex House, King William Street, London, E.C.4.

ZINC ROOFING

Zinc as a roof covering is not now so much used as formerly, but it is a durable roofing material if of suitable thickness (at least 16 gauge) and properly fixed.

It is produced from metal ores known as calamine, blend, or black jack, the ore being roasted, mixed with charcoal, and heated in special retorts. In England the ores are found in Cornwall, Cumberland, Derbyshire, and the Mendip Hills in Somerset.

Zinc is bluish white in colour and brittle when cold, but at a temperature of 220° F. it can be rolled into sheets which can be bent without cracking. A good zinc is lighter in colour than a poor zinc, which may also be distinguished by its blotchy appearance.

Sizes and Gauges.—Zinc is sold in sheets 7 feet × 2 feet 8 inches; 7 × 3 feet, and 8 × 3 feet, and distinguished by their gauge, which is

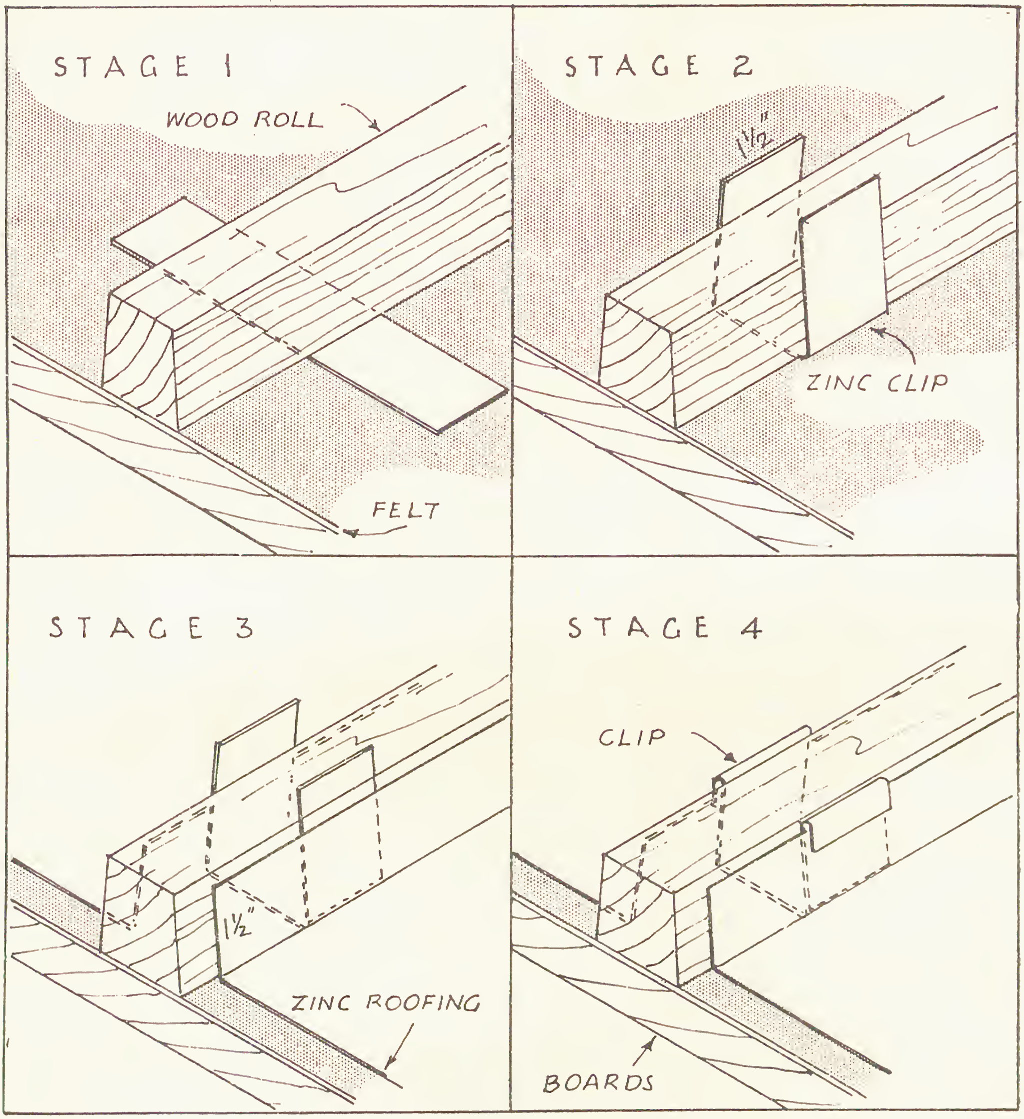


Fig. 281.—Wood rolls and clips in zinc roofing

the thickness. The table on p. 346 (Rivingtons) gives the weight of zinc per square foot for the various gauges, those from 10 to 21 gauge, except 18, having been accurately measured and furnished by Messrs. Braby: for temporary work gauges 10 to 12 are used, but for permanent better-class work, no lighter gauge than 16 is recommended.

Rolls are formed in zinc roofings for the same purpose as with lead, but as this material does not lend itself to dressing round circular shapes, but rather to bending, the rolls are of a square formation, but narrower at the top than the bottom, an average-sized roll being $1\frac{1}{8}$ inches at the

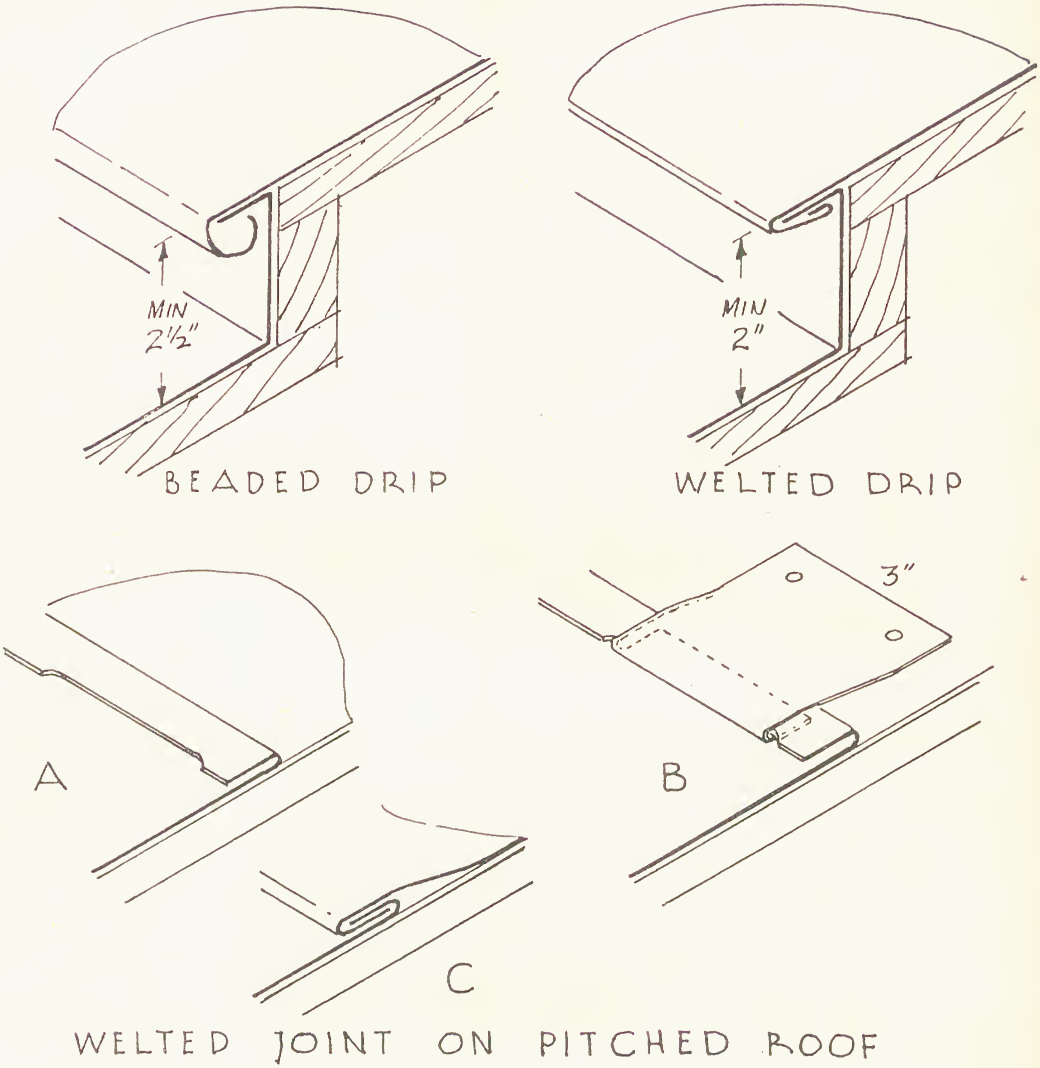


Fig. 282.—Zinc roofing—drips and welted joints.

top and $1\frac{5}{8}$ inches at the bottom by $1\frac{5}{8}$ inches high. The edges of the sheets are turned up against the sides of the roll and secured with zinc clips turned down over them and under the roll before it is fixed. A capping is then fixed over the roll and turned down at the sides over the turn-up edges of the sheets.

Drips in zincwork have the edges of the lower sheet turned upwards and then outwards, and the edge of the covering sheet bent round under this projecting edge.

Corrugated Zinc is used for roofing without boarding, the corrugations being $3\frac{1}{2}$ inches wide ; and it is laid in the same manner as corrugated

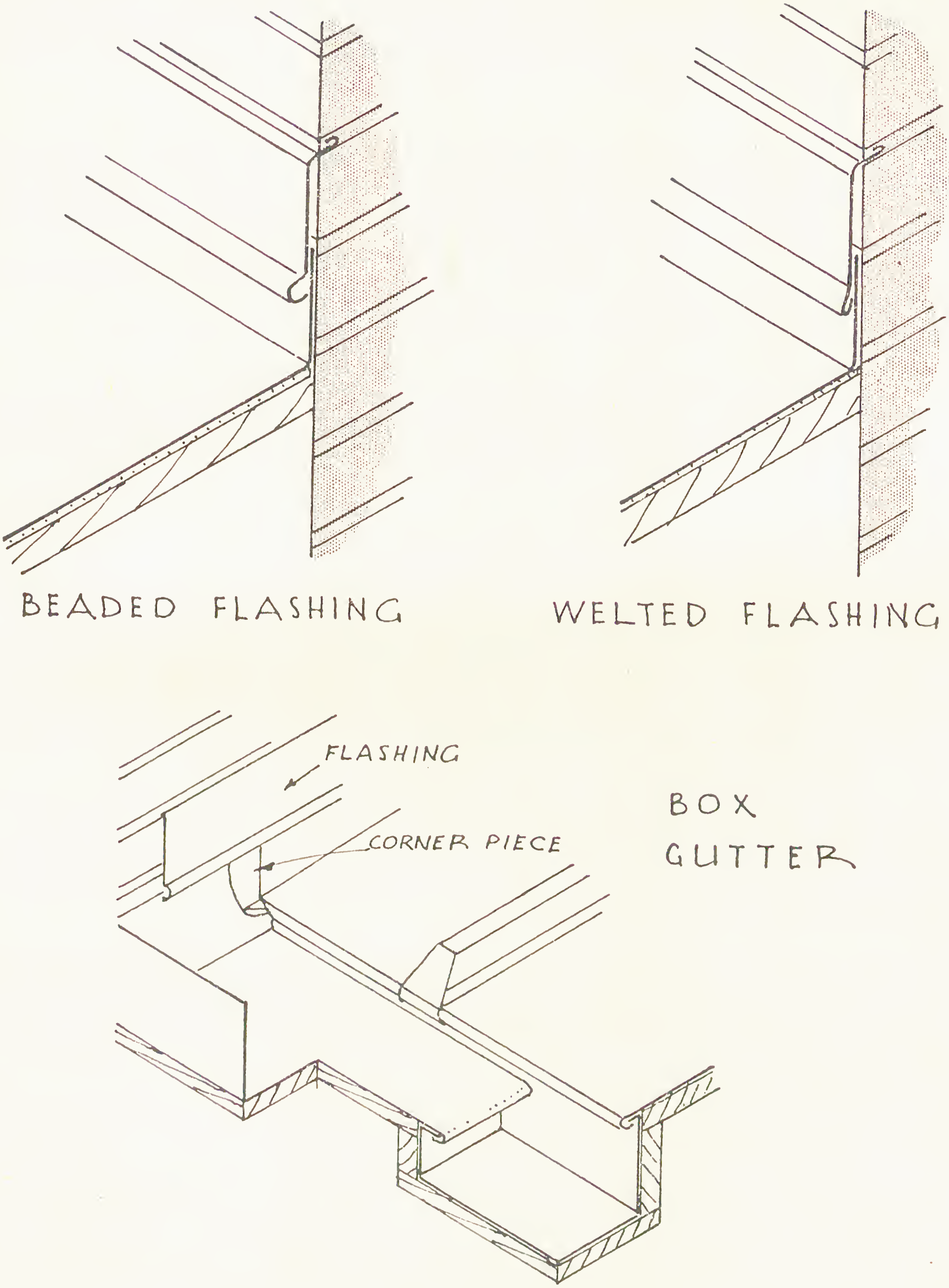


Fig. 283.—Zinc roofing—flashings and box gutter.

iron, *i.e.* with the corrugations run down the roof. The corrugations are overlapped at the sides, and should be screwed at the top and bottom edges to the roof timbers.

WEIGHTS OF ZINC ROOFING

Gauge.	Approximate weight per square foot. Lb.	Oz.	Dr.	Approximate thickness. Inches.	Gauge.	Approximate weight per square foot Lb	Oz.	Dr.	Approximate thickness. Inches.
1	0	1	2	·0018	14	1	2	12	·0326
2	0	2	4	·0036	15	1	5	12	·0364
3	0	3	7	·0055	16	1	8	12	·0400
4	0	4	9	·0073	17	1	11	11	·0437
5	0	5	11	·0091	18	1	14	11	·0478
6	0	6	14	·0110	19	2	1	11	·0509
7	0	8	0	·0128	20	2	4	10	·0581
8	0	9	2	·0146	21	2	8	2	·0728
9	0	10	5	·0165	22	2	12	14	·0764
10	0	11	7	·0180	23	3	1	1	·0800
11	0	13	5	·0217	24	3	5	3	·0896
12	0	15	2	·0254	25	3	9	5	·0992
13	1	0	15	·0290	26	3	13	7	·1088

Nails.—As zinc must not be allowed to come in contact with iron, copper, or lead, an action being set up which destroys the zinc, zinc nails must be used. It is not, however, a suitable roofing for cities or towns where manufactures are carried on, as the acids in the air soon destroy it. The expansion and contraction of zinc being greater than that of lead, it is even more important that it should be fixed so that it is free to move.

Correct roofing practice in zinc is described in detail in publications issued by the Zinc Development Association, Gt. Westminster House, Horseferry Road, London, S.W.1.

COPPER ROOFING

Although copper is a traditional roofing material, and there are many old examples in Britain which are still in good condition, it is only in recent years that its use has become widespread. It is light, durable, and of pleasing colour.

The two gauges in general use are :

23 S.W.G., nominal weight 19 oz. per sq. ft.
24 S.W.G., nominal weight 16 oz. per sq. ft.

The 24 gauge is the lightest which should be used for permanent roofing.

The size of sheet generally used is 14 square feet—7 feet × 2 feet or 4 feet × 3 feet 6 inches, to give two examples, but 8 feet × 3 feet sheets are sometimes preferred as the larger size reduces labour in jointing.

Strip copper is supplied in long rolls, and is used for valleys, gutters, cornices, flashings, etc.

Sub-roofing.—Copper can be laid on boarded or cemented surfaces, flat or pitched. The minimum pitch for flat roofs is $1\frac{1}{2}$ inches in 10 feet. On pitched roofs copper can be used on any angle, and it does not creep on a steep roof.

A layer of bituminous underfelt or building paper should be laid over the boards or cement screeding. This prevents contact with any iron nail heads, protects a boarded roof from dampness which might be caused

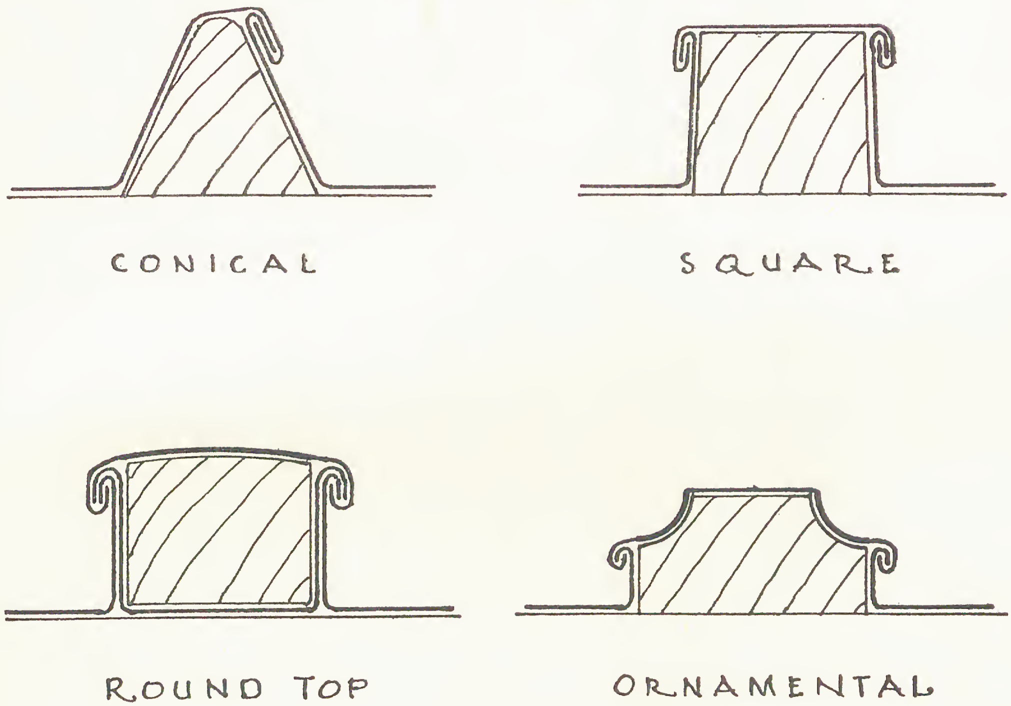


Fig. 284.—Copper roofing—wood rolls.

by condensation under the copper, and improves the thermal and sound insulation of the roof.

Jointing.—There are two efficient methods of jointing: the standing seam and the wood roll. Both allow for expansion while retaining weathertightness.

The standing seam is particularly suitable for pitched roofs, but is not much used for flat roofs as it is liable to be bent and damaged by treading. It is a simple joint and as it stands above the water running down the roof there is no point at which water can penetrate.

The wood roll joints are of several types, some of which are illustrated in Fig. 284. The conical roll is the simplest though it does not allow so much for expansion as the others.

The cross welts or joints which link the sheets end to end are illustrated in Fig. 285. The single lock welt is suitable for steep pitches and the double lock for flat roofs.

Eaves.—Where the copper overhangs the gutter and at the ridge,

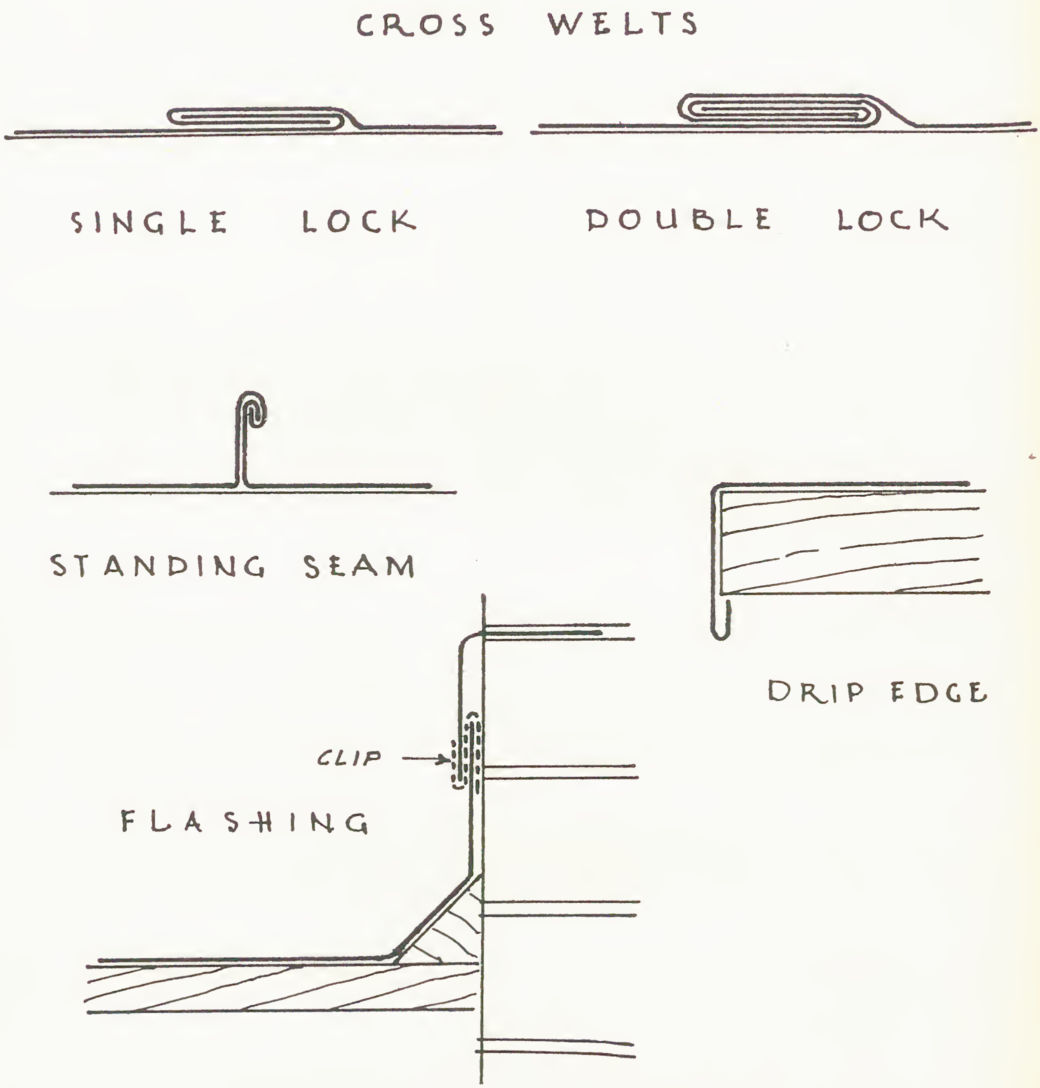


Fig. 285.—Copper roofing—welts, seams, and flashings

certain adjustments are required. The copper may be simply turned down the boarding into the gutter and tacked along the butt of the boarding; or a better practice is to shape the copper into drips with the nails underneath the projecting lip. The bottom strip is either used wider than those above, or the board is cut narrower, the desired effect being the same in either case. This is to fix the strip at both sides, *i.e.* top and bottom, on a board for which it is too wide. This gives a bellying

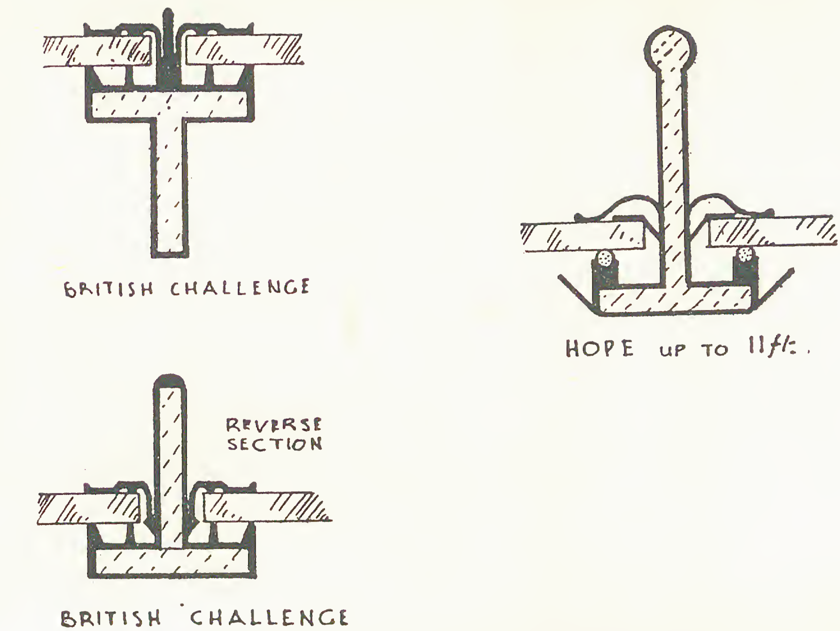


Fig. 286.—Steel lead-covered glazing bars.

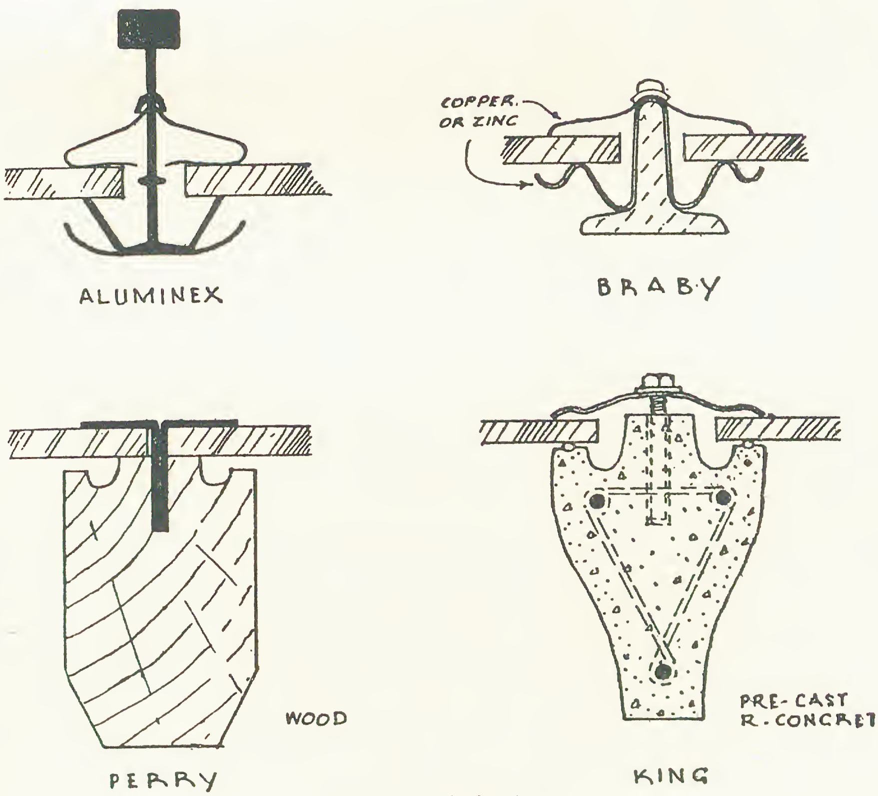


Fig. 287.—Glazing bars.

out line to the surface of the copper, which is worked down flat to the bottom of the board to form a projection beyond the edge of the board. This projection is then beaten down to form a drip and to afford a covering to the nails holding it to the edge of the boarding.

Ridge.—The ridge may be formed of a simple welt laid to one side of the ridge board along the roof, the feather-edge boarding against the

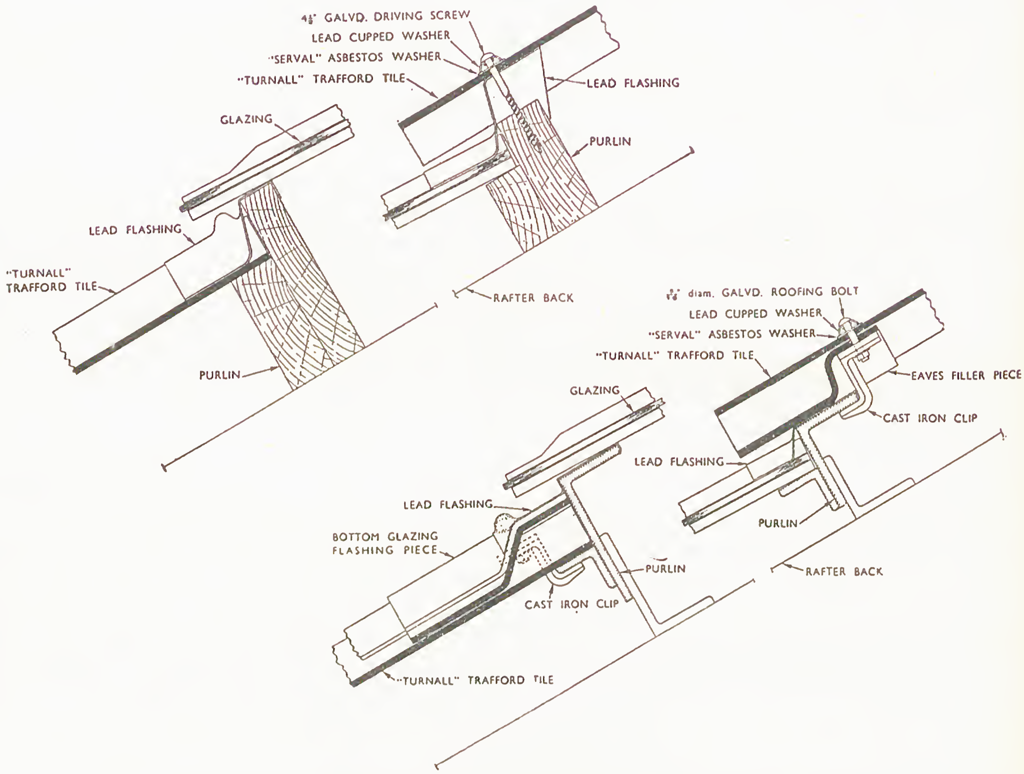


Fig. 288.—Roof glazing: (top) wood purlins; (bottom) steel purlins.

ridge being cut narrower than the width of the ordinary courses. One of the strips is then bent over the ridge and engaged with the other strip in a welt.

An alternative method is to turn the top edges of both strips up against the ridge-board and then to beat it down on to the top of the ridge-board and nail both strips at the side and on the top. A specially formed hollow copper ridge is then laid over having a fold at each side which is turned up for nailing and then turned down to cover the nails.

Copper roofing is a specialist tradesman's job, and it is interesting to note that the Copper Development Association of Kendals Hall, Radlett, Herts, has opened, with the co-operation of the Institute of Plumbers, a register of firms prepared to carry out work in copper.

ROOF GLAZING

The bars and framing members used to support roof glass are made of wood, steel, copper, aluminium alloy, and pre-cast reinforced concrete.

The traditional type of glazing bar is the wood rebated bar, puttied to make a watertight joint between glass and bar.

Puttyless Bars.—These are now almost exclusively used. They may be of wood, metal, or pre-cast concrete, and typical examples are illustrated in Figs. 286 and 287.

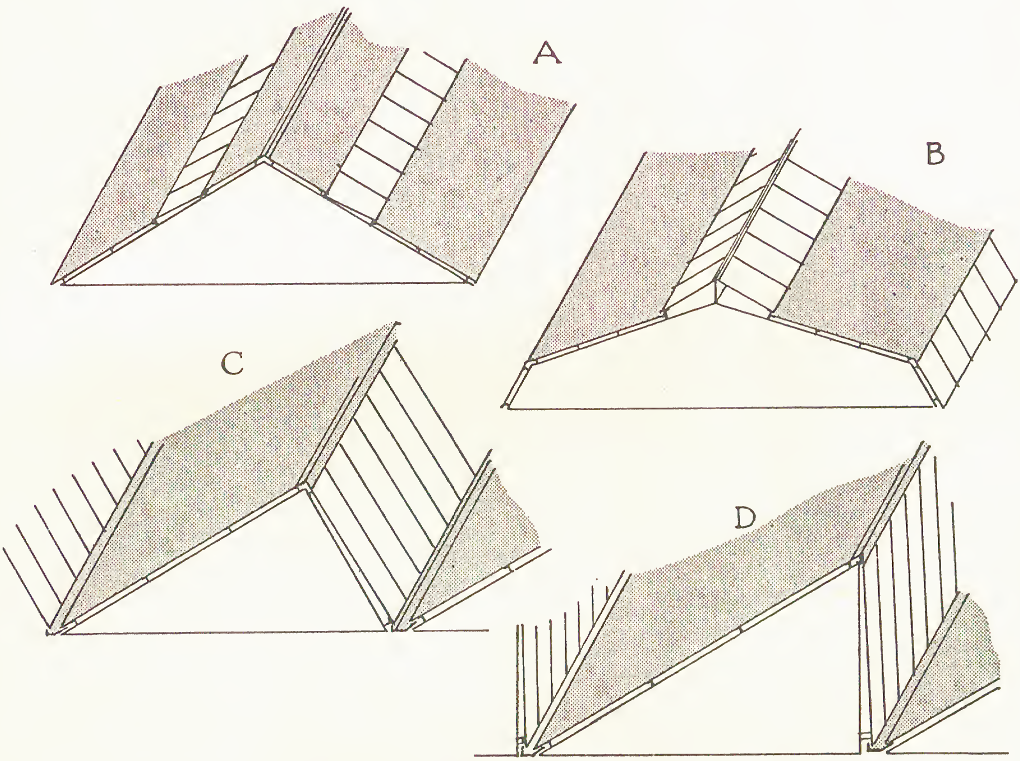


Fig. 289.—Roof glazing: typical arrangements. C and D are north-light roofs.

Steel bars are protected against corrosion by sheathing with lead or galvanising. Anti-capillary and condensation channels are incorporated in such bars. The glass is seated either on metal or asbestos cord. The edges of the glass are covered with a lead turn-down in some cases and with copper, zinc, or aluminium alloy curved strips in others.

There are several advantages in using metal or pre-cast concrete bars of the puttyless type. The material is proof against corrosion so that painting is not necessary. The bars, glass, and roof structure can expand and contract without risk of cracking the glass. The cover remains weathertight. The bars are of smaller section than the old-

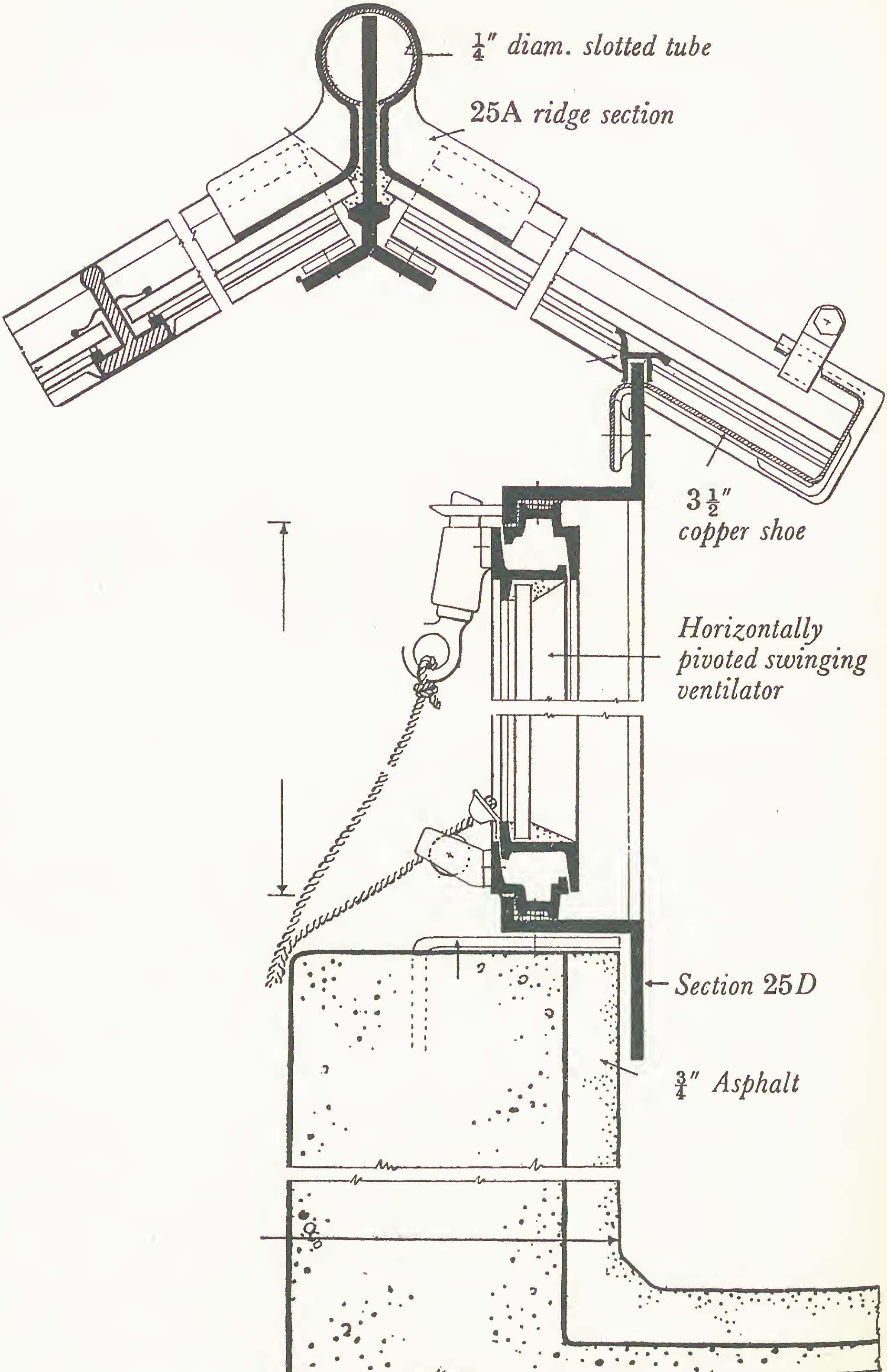


Fig. 290.—Detail section of lantern light showing fixing to concrete kerb. (*Courtesy of Henry Hope & Sons, Ltd.*)

type wood bars and therefore stop less light. And, finally, they are easier to fix.

Fixing details are supplied by manufacturers and these should be carefully followed. In most cases special clips are supplied for fixing the head and foot of the bar, and the foot clip also holds the edge of the glass so that it cannot slip.

Lantern Lights.—The old type of wood lantern light, specially designed and made for the individual job, is now rarely used. It has been supplanted by the new steel lantern lights. These are made in a range of standard sizes and patterns which meet all ordinary cases.

The roofs of such lantern lights consist of metal glazing bars of the puttyless type, and the sides of fixed or opening steel casements. These are framed together with steel sills, heads, and corners, the whole of the steel being rust-proofed.